S. Hrg. 101-348

NASA AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

ON

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION BUDGET

FEBRUARY 9, MARCH 16, APRIL 4, 11, MAY 11, AND 17, 1989

Printed for the use of the
Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE
99-657 O WASHINGTON : 1989

S 261-10

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ERNEST F. HOLLINGS, South Carolina, *Chairman*

DANIEL K. INOUYE, Hawaii
WENDELL H. FORD, Kentucky
J. JAMES EXON, Nebraska
ALBERT GORE, JR., Tennessee
JOHN D. ROCKEFELLER IV, West Virginia
LLOYD BENTSEN, Texas
JOHN F. KERRY, Massachusetts
JOHN B. BREAUX, Louisiana
RICHARD H. BRYAN, Nevada
CHARLES S. ROBB, Virginia

JOHN C. DANFORTH, Missouri
BOB PACKWOOD, Oregon
LARRY PRESSLER, South Dakota
TED STEVENS, Alaska
ROBERT W. KASTEN, JR., Wisconsin
JOHN McCAIN, Arizona
CONRAD BURNS, Montana
SLADE GORTON, Washington
TRENT LOTT, Mississippi

RALPH B. EVERETT, *Chief Counsel and Staff Director*
WALTER B. McCORMICK, JR., *Minority Chief Counsel and Staff Director*

CONTENTS

Page
Opening statement by Senator Gore 1
Opening statement by the Chairman 3
Opening statement by Senator Pressler 5
Opening statement by Senator Kasten 6
Opening statement by Senator Bentsen 6
Opening statement by Senator Robb 7
Opening statement by Senator Lott 7

CHRONOLOGICAL LIST OF WITNESSES

FEBRUARY 9, 1989

Fletcher, Dr. James C., Administrator, NASA 7
  Prepared statement 10
  Questions of Senator Gore and the answers 60
  Questions of Senator Gorton and the answers 73

MARCH 16, 1989

Opening statement by Senator Gore 75
Opening statement by Senator Pressler 76
Opening statement by Senator Lott 105
Greenwood, Lawrence R., general manager, spacecraft operations, Astro Space Division, GE 131
  Prepared statement 133
Hallinan, George J., vice president for space station power, Rocketdyne 134
  Prepared statement 137
Odom, James B., Associate Administrator for Space Station, NASA; accompanied by Raymond Tanner, Director, Space Station Freedom Program; Paul Anderson, Director, Insitional Resources Analysis Office 77
  Prepared statement 80
  Questions of Senator Gore and the answers 107
Thompson, Robert F., vice president and general manager, Space Station Division, McDonnell Douglas Space Systems Co 125
  Prepared statement 128
Winch, John B., director, program management office, Space Station Program, Boeing Aerospace 115
  Prepared statement 118

APRIL 4, 1989

Opening statement by the Chairman 165
Opening statement by Senator Kasten 166
Opening statement by Senator Pressler 166
Ballhaus, William, Director, Ames Research Center, NASA; accompanied by Dr. Robert Rosen, Acting Associate Administrator for the Office of Aeronautics and Space Technology 167
  Prepared statement 170
  Questions of Senator Gore and the answers 187
Doniger, David, director, ozone protection program, Natural Resources Defense Council 220
Krone, Dr. Norris, American Institute of Aeronautics and Astronautics 216
Rowberg, Dr. Richard E., Chief Scientist, Policy Research Division, CRS, Library of Congress; accompanied by Dr. Christopher T. Hill, Senior Specialist in Science and Technology Policy 199
  Prepared statement 201

Swihart, John M., president, National Center for Advanced Technologies, Aerospace Industries Association of America 213
Wickens, Ronald, vice president of engineering and quality assurance, Federal Express 217

APRIL 11, 1989

Opening statement by the Chairman 233
Opening statement by Senator Pressler 234
Opening statement by Senator Rockefeller 235
Fisk, Dr. Lennard A., Associate Administrator, Office of Space Science and Applications, NASA; accompanied by Sam Keller, Deputy Associate Administrator; and Catherine Schmoll, Assistant Associate Adminnistrator 236
  Prepared statement 239
  Questions of Senator Gore and the answers 270
Lanzerotti, Dr. Louis, chairman, space studies board, National Research Council of the National Academy of Sciences 286
  Prepared statement 289
Solomon, Dr. Sean, chairman, space science working group, Association of American Universities 306
  Prepared statement 307

MAY 11, 1989

Opening statement by Senator Gore 333
Opening statement by the Chairman 235
Opening statement by Senator Lott 379
Opening statement by Senator Pressler 382
Donlan, Charles J., Aerospace Safety Advisory Panel, NASA; accompanied by Seymour C. Himmel; Adm. Richard H. Truly Associate Administrator, Office of Space Flight, James R. Thompson, Director, George C. Marshall Space Flight Center; George A. Rodney, Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance 399
  Prepared statement 402
  Questions of Senator Gore and the answers 433
  Questions of Senator Garn and the answers 449
Garn, Hon. Jake, U.S. Senator from Utah 417
Heflin, Hon. Howell, U.S. Senator from Alabama 412
Truly, Adm. Richard H., Associate Administrator, Office of Space Flight, NASA; accompanied by Arnold Aldrich, Director, Space Shuttle Program; Joseph Mahon, Deputy for Flight Systems; and Lowell Zoller, Chairman, Source Evaluatuation Board, Marshall Space Flight Center 336
  Prepared statement 340
  Questions of Senator Gore and the answers 351
  Questions of Senator Garn and the answers 356

MAY 17, 1989

Opening statement by Senator Gore 455
Opening statement by Senator Kasten 457
Opening statement by Senator Lott 501
Miller, Stephanie Lee, Director, Office of Commercial Space Transportation, DOT; accompanied by Gerald Musarra, Program Counsel; and Norman Bowles, ssociate Director for Licensing Programs 526
  Questions of Senator Gore and the answers 535
Rose, James T., Assistant Administrator for the Office of Commercial Programs, NASA; accompanied by Edward Frankel, General Counsel; and William McGarvey, Assistant Associate Administrator for Facilities Management 457
  Prepared statement 464
  Questions of Senator Gore and the answers 517

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

Aftergood, Steven, Federation of American Scientists, statement 564
Cochran, Hon. Thad, U.S. Senator from Mississippi, statement 539
Grey, Jerry, director, science and technology policy, American Institute of Aeronautics and Astronautics, statement 540

NASA AUTHORIZATION

THURSDAY, FEBRUARY 9, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met at 9:30 a.m. in room SR–253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Marty Kress; Mike Nelson, professional staff members; Sherman Joyce; and Louis Whitsett, minority staff counsels.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The subcommittee will come to order. I would like to welcome our witnesses and our guests to the subcommittee's first hearing in the 101st Congress. I would also like to welcome the new members of the subcommittee.

I am very honored and proud to be chairman of the subcommittee and look forward to working very, very closely with the chairman of our full committee, Senator Hollings, our ranking member, Senator Pressler, and the ranking member of the full committee, Senator Danforth, as well.

I look forward to this hearing this morning. Before we receive the testimony, I would like to say just a few words and then invite the Chairman of our full committee to proceed.

This year we hope to explore fully the status of the nation's space, science and technology programs. Currently the subcommittee has three hearings already scheduled and quite a few others in the works.

We hope to have an ambitious agenda in place in the next three months, and based on the goals that I have discussed with the chairman and with the staff, I intend to hold hearings on all of the major programmatic areas within NASA and, in addition, the scientific questions concerning global changes. Other hearings will address computer policy, superconductivity, and advanced computers, high-definition television, private sector financing, space commercialization and a number of other subjects. It is an ambitious schedule, but one that we must meet if we are to gather the information required to craft some innovative legislative initiatives.

Today in our first hearing we are honored to initiate the subcommittee's ambitious schedule with Dr. James C. Fletcher, the Administrator of NASA, and Mr. Thomas Campbell, the Comptroller of NASA, who are here to present former President Reagan's FY

1990 and FY 1991 budget request. We intend to explore this budget request very thoroughly today since it is clear that it is going to be the baseline for further amendments by President Bush and for any budget summit discussions.

Realizing that NASA is one of the few areas in President Reagan's FY 1990 budget request to receive a proposed increase in FY 1990, a very substantial increase of 22 percent, it will be necessary for the subcommittee to understand thoroughly the composition of this request and its relationship to sustained U.S. technological leadership in space if we are to be able to argue fully and convincingly for inclusion of comparable funding levels in the final congressional budget.

Today we hope to explore closely the relationship of the proposed FY 1990 budget request to the resource requirements of the ongoing NASA program and to the resource requirements of the civil space program's agenda for the 21st century.

To facilitate that discussion, I have asked the staff to prepare a series of charts comparing prior year NASA budget requests to the final appropriations level, the FY 1990 budget request to less robust budget levels, and the CBO baseline for FY 1990 with the funding levels required to implement the dreams and hopes of the space program for the 21st century.

Now, based on a preliminary analysis, it seems to me that NASA's FY 1990 budget request of $13.3 billion, including what I believe can fairly be labeled private financing gimmicks, is barely enough to implement NASA's ongoing programs, let alone initiate the new activities that the members of the subcommittee and various advisory groups feel are required if the U.S. is retain leadership in space.

So, today we will start our review of the nation's space program. As the months progress, the members of the subcommittee will be asked to make three critical choices: First, we will need to decide if the proposed NASA FY 1990 budget request provides the money, people and programs required to implement the nation's ongoing space program, to maintain U.S. leadership in space in the 21st century, and to meet the ever increasing challenges of foreign competition. Second, we will need to decide if the Congress will be able to include the necessary funds in the budget to attain these objectives. And, third, we will need to decide how to realign the program if Congress is not willing to provide the necessary resources.

I have long been an ardent supporter of the nation's space program and feel very strongly that the American public shares that enthusiasm. Unfortunately, implementation of this program requires substantial budget increases over the next few years just to implement the ongoing program, let alone initiate any bold new initiatives.

So, the challenge for our subcommittee will be to become so well versed in the value of the space program that we will be able to convince 50 additional senators that funding for the civil space program must be a budget priority when we vote for the budget resolution, the authorization bill, and the appropriations bill.

Dr. Fletcher, we welcome you. In your most recent reign as Administrator of NASA you have been able to return the space shuttle to flight status, to negotiate a complex series of international agreements for development and deployment of a permanently manned space station, to convince OMB that funds must be provided to improve NASA's infrastructure, and to hire additional personnel—NASA's most precious resource.

However, today and during the course of the next few weeks, you will have, perhaps, your most difficult challenge, helping us convince the Congress that the levels of funding requested in the FY 1990 and 1991 budget request must be included in the final congressional budget if this nation is to retain its leadership in space.

Now, before asking you to proceed, I wish to turn to the Chairman of the full committee and invite him to get us off to a good start, and then I will turn to our ranking member of the subcommittee.

OPENING STATEMENT BY THE CHAIRMAN

The Chairman. Thank you, Mr. Chairman. I congratulate you and your ranking member, Senator Pressler. Under the leadership of both of you I am confident we will get back in this race for space. You are the Commerce Committee's first subcommittee and first subcommittee chairman to hold hearings this Congress.

Dr. Fletcher, the committee is indebted to you, and that is really why I came to thank you on behalf of our committee, the Congress, and the people of America for bringing order out of chaos to our space program and for instilling pride where there was despair and hope where we had, in a sense, almost given up.

You have done an outstanding job for the country, and I thought someone ought to come up here and tell you that. We on the Committee know it best because we worked through those stormy days, and we will continue to work through these stormy days trying to obtain sufficient funds.

Today, the Subcommittee on Science, Technology, and Space will initiate hearings on the NASA budget requests for FY 1990 and FY 1991. Despite the fact the Committee anticipates changes to these proposed levels when President Bush submits his FY 1990 budget request, it is clear to me that the more we know about our civil space program and its resource requirements, the better case we will be able to make when these issues are discussed during formulation of the final NASA authorization and appropriations bills. Therefore, I am pleased to see the Subcommittee taking action on this important matter.

Unfortunately, based on reports in the press, the trade journals, and leading industry dailies, it appears that we find ourselves in the same situation in FY 1990 that we were in, in FY 1989. We find ourselves trying to justify a proposed NASA budget increase of 22 percent when most federal programs are lucky to get inflation adjustments, and many federal programs (82) are proposed for termination. Worse yet, the proposed 22 percent increase for NASA is hardly enough to meet NASA's current services requirements for the programs approved in FY 1989.

Mr. Chairman, it's high time that this Committee and the Congress resolve, once and for all, the debate over federal spending for the civil space program. It's time for us to commit to the goal of retaining U.S. leadership in space and to provide the resources required to implement this agenda. It's time for us to realize that our lead in space has been seriously eroded and that many countries are positioning themselves to reap the benefits of our investment. While we debate whether we can afford the civil space program, the Soviet Union, ESA and Japan are augmenting their space budgets and positioning themselves to capture markets once dominated by the United States.

Mr. Chairman, during the last decade, America's steel, auto, consumer electronic and clothing industries all have been victimized by overseas competition. And now, the United States, the Nation that has made the greatest contribution of space technology to the world, is in danger of losing that lead as well. That's unconscionable! It's high time that we quit debating what we ought to do and do something. It's high time that we give NASA the resources—people, dollars and facilities—required to maintain our leadership position in space and aeronautics and to implement our civil space program.

Mr. Chairman, twenty years ago, Neil Armstrong put his footprints on the surface of the moon. It was an event that captured the spirit and imagination of the American people and the world. To accomplish that feat took commitment, resources, people and imagination—the same ingredients it will take to deploy a permanently manned space station, initiate a Mission to Planet Earth or send a manned mission to Mars. Isn't it about time that the Congress and White House agreed to provide these ingredients to NASA so that twenty years from now we have more to talk about than Apollo.

Mr. Chairman, I believe strongly that the civil space program is important to our national and economic security and that it should be a budget priority. I look forward to Dr. Fletcher's testimony on behalf of this year's budget request, and I hope that the final FY 1990 NASA authorization and appropriations bills provide the support our civil space program deserves.

Finally, I would be remiss if I did not publicly thank Dr. Fletcher for the job he has done at NASA over the last three years. Dr. Fletcher, you have provided an invaluable service to NASA and to the Nation during difficult times, and you are to be congratulated. I know the last three years have not been easy. Accident investigations, budget battles, and grounded space shuttles are never easy to deal with, but you did it. And because of your efforts, the space shuttle is flying, the space station is being developed, and NASA has regained its reputation.

Thank you, Dr. Fletcher. And thank you, Mr. Chairman.

I would like to ask one question, and that is will the additional two and a half billion dollars, do it in FY 1990?

Last year, we were talking about a possible increase of four and a half billion. Will two and a half really keep the shuttle up and keep the space station program on schedule? Is the FY 1990 budget request sufficient funds for these tasks?

Dr. FLETCHER. If the Congress signs up for the full budget, we can squeak by, Senator Hollings, but we did have to drop a number of programs, and we did have to tie a number of others. So it is a marginal to submarginal budget.

The **Chairman**. Marginal to submarginal. That is what I feared because I know on the other hand when we get into the budget committee and everyone is picking on the next fellow's program and they cut a billion a year, if a billion was cut out of the two and a half billion, then we would have to go back to the drawing boards entirely, would we not?

Dr. **Fletcher**. That is my opinion at this point, although we have not really contemplated such a large cut. But we would have to go back to the drawing board, I expect.

The **Chairman**. Thank you very, very much, Mr. Chairman. I thank Senator Pressler for yielding.

Senator **Gore**. Senator Pressler.

OPENING STATEMENT BY SENATOR PRESSLER

Senator **Pressler**. Thank you very much, Mr. Chairman, for your early start on these matters. I look forward to working with you in the coming two years. I look forward also to working with the chairman of our full committee and the other members.

I think this is a very important hearing on the NASA budget. This is a big year for NASA, and it is imperative that the Science, Technology, and Space Subcommittee, as well as the Congress, understand fully the agency's budget requirements as we approach the next decade.

NASA received a 22 percent increase in fiscal year 1990. This increase makes NASA an inviting target for cuts during the appropriations process. We must examine the implications of possible cuts on NASA's program in the near term as well as the long-term prospects for the agency.

The space shuttle returned successfully to flight last September, and the Space Station "Freedom" is now beyond the drawing board phase. Clearly this is a critical juncture for NASA, and we in the Congress will be called upon to make difficult decisions about federal spending in these days of spiraling deficits. One of the most difficult will be the spending level for the space program.

Dr. Fletcher, you, in particular, have done a commendable job at NASA during very difficult times. All of you have done a terrific job under the conditions and the budgets which you've operated under.

The agency now is flying missions again, and we still face tough decisions about funding for future activities. I am particularly concerned about impact of possible cuts on the space station program.

Now, as I said informally before this meeting, I would also invite any of you to comment on the salaries of employees and retention of those employees.

I thank you for appearing today before the subcommittee, and I look forward to your testimony. And I do apologize if I have to come and go here this morning. I am also on the Banking Committee, and we have a small problem over there we are trying to solve—the S&Ls. So, I will be getting my questions in on both committees this morning.

But, I welcome you here.

Senator **Gore**. Thank you, Senator Pressler. I look forward to working with you during this Congress.

We are going to proceed on the basis of the order of arrival. The next member to arrive was Senator Kasten, and I want to welcome him as a new member to the subcommittee.

OPENING STATEMENT BY SENATOR KASTEN

Senator **Kasten**. Mr. Chairman, thank you. I look forward to working with you and the other members of the subcommittee.

The budget presentation today is but one of the areas in which we are going to be working in trying to deal with funding priorities. And the funding is tight. But the priorities are of critical importance and they are going to determine the program priorities.

I also want to thank and congratulate Dr. Fletcher.

Senator **Gore**. Senator Bentsen has been perhaps one of the most active members in space policy on the entire committee. I am honored to have a chance to work with him.

OPENING STATEMENT BY SENATOR BENTSEN

Senator **Bentsen**. Thank you very much, Mr. Chairman. I am delighted to be here.

Dr. Fletcher, I want to join the accolades. You have done a good job in restoring morale and some specificity and objectives for NASA. We could use that kind of talent over at FSLIC right now.

We are going to have a tough job defending this budget because with all of the constraints and trying to cut this deficit down as we must, this is one of those programs that has a substantial increase. Therefore, we need your help on the missionary work that has to be done, and we appreciate any of it we can get.

But even so, I am concerned about some of the assumptions here, the third-party financing, wondering if it really is valid and realistic that we can get that much private sector money and the wisdom of doing some of that.

But I will be looking forward to doing what we can to see that we continue to regain our leadership in space.

And I would also say to some of our colleagues that OMB has already cut this budget request by something on the order of a billion dollars, some of these major programs like the shuttle and the space station. Unless you can get sufficient money to do these programs well, they are really killing the projects, and they must bear that in mind. So, that is the importance of defending this budget and seeing that we are able to fulfill it.

Let me say to you, Mr. Chairman, I am delighted you are moving forward as quickly as you are. And as I look at the agenda for this subcommittee and for the full committee with superconductivity, advanced computers, and high-definition television, you are really going to be in some very major, critical areas for the country, and I wish you well in it.

Senator **Gore**. We feel fortunate to have you helping and advising the committee. Thank you. I want to associate myself completely with all of your remarks about the budget, which we will be getting into in great detail.

I am delighted that my long time friend, Senator Chuck Robb, is a new member of the subcommittee. Welcome.

OPENING STATEMENT BY SENATOR ROBB

Senator **Robb**. Mr. Chairman, thank you. I am delighted to be a member of this subcommittee. I look forward to the deliberations.

My own state has a number of interests in our country's ability to fulfill its challenges in the space arena, and so I have a parochial interest as well as a national interest in this particular topic.

As both a new Member of Congress and a new member of this committee, I look forward to working with you, and I will be pleased to participate in the deliberations as we move along, but I have no specific opening statement.

Senator **Gore**. Another friend from the House days and another new member of the subcommittee, Senator Lott. Welcome.

OPENING STATEMENT BY SENATOR LOTT

Senator **Lott**. Thank you, Mr. Chairman. I am going to say to you it is a pleasure for me to be a member of this subcommittee, and I want to congratulate you as the subcommittee chairman and the full committee chairman for having these early hearings. This, I guess, would be my first hearing as a member of the Senate, and I am looking forward to it.

I want to say we are looking forward to hearing from you, Mr. Administrator. I also am very much concerned about making sure that NASA has the budget it needs to do the job.

Many of your programs do affect my own state, as the gentleman from Virginia just pointed out regarding his state, but also many of your programs, I think, affect the future of our country and our ability to be competitive in so many fields. So, I am anxious to participate in these hearings, and as a member of this subcommittee I hope to assist you and your agency in performing a very vital function for the future of our country.

Thank you, Mr. Chairman.

Senator **Gore**. Thank you. For the record, I want to note that the subcommittee welcomes our other two new members, Senator Bryan and Senator Stevens and welcomes back the other former members of the subcommittee, Senator Rockefeller and Senator Kerry.

Dr. Fletcher, thank you for your patience. Let me note that you are accompanied not only by Mr. Campbell, your comptroller, who I mentioned earlier, but also Mr. Dale Myers, Deputy Administrator of NASA, and Dr. Noel Hinners, Associate Deputy Administrator of NASA, and we are delighted to have all of you present.

I understand your statement, Dr. Fletcher, will be the only formal statement, and your colleagues are joining you to respond to questions following after your statement.

Dr. **Fletcher**. That is correct, Mr. Chairman.

Senator **Gore**. Welcome, and please proceed.

STATEMENT OF DR. JAMES C. FLETCHER, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. **Fletcher**. Mr. Chairman, with your permission, I would like to submit the formal statement for the record.

Senator **Gore**. Without objection.

Dr. FLETCHER. And I will kind of summarize where I think we are. It is indeed true that we have had two successful flights and on the surface it looks like we are fully recovered from the Challenger accident. But, in fact, we have got a long way to go to put NASA back on the track where it ought to be, as you properly pointed out in your opening comments.

What I would like to do is simply point out the salient issues that are surrounding this budget request and then open it up for questions.

The breakdown of the appropriation goes something like this. There is about $5.8 billion for what we call research and development; there is $5.1 billion for what we call SFCDC—that is flight programs; $2 billion for R&PM, that is people and the equipment and the facilities to support those people; and then $342 million for facilities. That comes to, as was pointed out, $13.3 billion total.

I think also as was pointed out this is actually less than last year's runout, and so it really is a rather tight budget. 1 percent of this budget is for new work and there is only one new spacecraft start, and that is the Mariner II missions to Saturn and to a comet. That is what we call the CRAF/Cassini mission.

We pointed out last year that the $13.3 billion that we expected as a runout of last year's decisions were needed to continue the careful program of spaceflight recovery and involvement, and we do have to move more than two flights. We have got five flights this year, and we have got it up to seven flights next year, and we do need the money to do that.

We also need it to continue the full-scale development of the Space Station Freedom, as you pointed out. We also need it to continue a major emphasis on global change research, and advanced technology development for future systems.

We need it to maintain a strong forward pace in our science and aeronautics activities, and we need it to keep our core technical capabilities both dynamic and productive. The fiscal 1990 budget is within that amount and perhaps marginal in that regard.

It goes without saying that this is an extremely tight budget being submitted and an extremely tight budget year. We have already had to accommodate, as you pointed out, a significant reduction in our aspirations in the budget process.

What remains in our $13.3 budget has left very little flexibility. We talked about restructuring. If we do not get the full amount, I do not know quite how to do that at this point.

This budget is predicated on private sector investment, as you pointed out, and several time critical program elements. We really need those facilities in order to get on with the space station, a good many of them.

Taken together, these private initiatives represent more than $200 million of what would normally be included in the fiscal 1990 program costs with an estimated runout of about $700 million.

Be assured that we are going to do our level best with your crucial help—we have to work together on this—to create the necessary environment to attract private sector investment in these facilities and developments, and we expect to see legislation for termination liability coverage, and we will have to contract artfully for the future services to make this approach work. It is not going to be an easy job.

I also want to make it clear that if we are not successful, we will have to come back seeking the appropriate budget amendments; that is, additional monies for those programs.

The past really is a prologue. We have worked extremely hard for the past three years, as you pointed out. We have made a lot of progress in returning the shuttle to flight status. The space station contractual effort is entering full-scale development at this point. Our bread and butter science and aeronautics programs and the technology efforts have developed a real dynamic momentum, and our long-term concern for understanding the Earth as a system is receiving global attention, not just in this country but throughout the world.

The challenge for NASA and the administration, the Congress, and the American people is to keep this integrated program on track and focused on our clear national long-range goals.

Let me underline once again what has been proven over and over again. If we are not willing to commit the energy and will and money that this program requires, we are not going to succeed. You cannot have a first class program by investing second class resources. And it is national investment that is at stake here, investment in humanity's future and in America's right to influence and guide that future.

We do not want to fall short of the deserved expectations of the nation, especially our young people, the next generation that we all serve.

That concludes my statement and we are open for questions, Mr. Chairman.

[The statement follows:]

Statement of

James C. Fletcher
Administrator

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space

Committee on Commerce, Science and Transportation

United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

I welcome this opportunity to discuss the FY 1990 budget request for NASA as submitted by President Reagan.

Overview

With the help of this Committee, as well as the other Committees that review our budget and the Congress as a whole, the Nation's space program is making a strong recovery. The shuttle is flying again, the replacement orbiter is well into production, and the space station is under development. A number of key science missions are about to fly. And the mixed fleet is a reality. In short, the space program is back on track. The challenge now for us in NASA, for the new Administration, and for you on Capitol Hill, is to keep it on track to sustain and build on the forward momentum toward our long-range goals in space.

We have had two successful shuttle flights, but only two. We still have many flights to go to reestablish full confidence, demonstrate reliability, and work off the backlog of scientific and national defense missions.

We have made a strong beginning with the Space Station Freedom Program. We have Congressional approval, we have a firm configuration, contractors have been selected and are at work, and formal agreements with our international partners are in place . And now, the real work of design, development and testing has begun.

Our science programs are in good shape, with several major projects awaiting their turn for a shuttle launch. The FY 1990 budget continues to provide strong support for space science.

Our studies toward long-term expansion of human presence and activity into the solar system are progressing, but we still have much to do before we fully understand the potential options, benefits and costs.

We are on the track laid out in the national space policy enunciated by President Reagan and in the FY 1989 budget. Your support - the actions of Congress last year - made it possible for us to move ahead without major programmatic changes. This FY 1990 budget request includes $13.3 billion for NASA, approximately $1.8 billion more than last year's request and $2.4 billion more than the FY 1989 appropriation. This is slightly less than the amount forecast a year ago when we presented the FY 1989 budget to you.

Virtually all of this increase is needed for programs presented and approved last year:

- the step by step build-up of space shuttle flight rate and development of the Advanced Solid Rocket Motor;
- the continued development of the space station;
- the Science and Applications, Aeronautics and Space Technology programs; and
- the necessary supporting activities

The fact that President Reagan approved this substantial increase in NASA's budget is strong testimony to the validity of the need and to the national importance of NASA's programs in space and aeronautics and the technologies they develop. In looking at the details, you will see the FY 1990 budget of $13.3 billion affirms this strong support for the space shuttle, the space station, space science and technology and aeronautics.

Let me highlight some of the key areas of this budget:

Space Transportation

Space Transportation activities - including the shuttle, upper stages, expendable launch services, spacelab and payload operations and related activities - will require nearly $4.7 billion in FY 1990. Our top priority goes to steady, long-term recovery and return of the shuttle to safe and reliable flight.

In the space shuttle, we have the world's most advanced system for getting people and payloads to and from Earth orbit, for carrying out U.S. scientific research in space, for stimulating commercial ventures, and for accomplishing many tasks in orbit, such as retrieval and repair of satellites, that cannot be done any other way. We sometimes forget the exciting and important missions already accomplished using the shuttle - the launch of major communications satellites, on-orbit repair of the Solar Maximum spacecraft, retrieval of defective spacecraft, and four major Spacelab missions. Indeed, these sophisticated missions are a testament to how much has been accomplished by the shuttle on 26 successful flights. At the same time, we must remember that this remains a complex developmental vehicle which will continue to require an extraordinary level of care and attention.

NASA's return-to-flight effort paid off with two successful flights in 1988 and, more importantly, with a revitalized shuttle fleet that is scheduled to deliver the more than 60 shuttle missions planned through 1994. Five shuttle flights are scheduled for FY 1989, followed by nine flights in FY 1990. The mission plan includes:

- the third Tracking and Data Relay Satellite, to be launched on the next flight;
- the Magellan mapping mission to Venus;
- the Galileo mission to explore the Jupiter system;
- the retrieval of the Long-Duration Exposure Facility;
- the Hubble Space Telescope, the first of the Great Observatories in Space; and,
- a Spacelab mission devoted to life sciences.

These missions scheduled during the next two years are just the beginning. For example, the longer term flight plan involves 23 Spacelab missions and many more missions important to science and to our national security.

The shuttle is the fundamental link in a space transportation infrastructure which will carry this Nation into the 21st century. It is our means to place human beings into orbit and it makes the Space Station Freedom possible and practical.

The FY 1990 budget provides the funding necessary for shuttle operations to support the planned missions and to proceed with the development of the Advanced Solid Rocket Motor to enhance the safety, reliability and performance of the shuttle. It provides funding for expendable launch services for scientific and operational payloads including the Global Geospace Science missions and the Mars Observer. In addition, the budget provides for the related Space Transportation Capability Development activities detailed in our budget request.

Space Station Freedom

The budget provides $2 billion to continue the planned build-up in funding for significant expansion of the development of the space station. The bulk of this funding will go to the four work package contractors to support detailed design activities. The development plan and basic configuration are firm, and the development contractors are making substantial progress. We are moving toward a first-element launch in early 1995 with a capability for man-tended research activity by the end of that year and a permanently manned capability by the end of 1996. Our international partners are committed, investing their resources and working on schedules consistent with this plan and with the agreements approved last fall.

Space Station Freedom is the best space station to meet our national objectives in Earth orbit and to support our long-term goals of expanding human presence and activity into the solar system. The space station is of the highest importance to the future of the civil space program.

In simple terms, Space Station Freedom is:

-- for science and technology,

a permanently manned research laboratory in space - where advanced research equipment and human intelligence can interact on the spot, where we can learn about the Earth's changing environment, and a place to learn about long-term human activity in space;

-- for human exploration of space,

a gateway for integration, test and departure for potential future missions; for human exploration of the solar system, all roads will pass through Space Station Freedom; and,

-- for international cooperation,

a clear, visible symbol of our commitment to peaceful leadership as a space-faring nation and of our readiness to cooperate with other nations in this great adventure.

Space Station Freedom is clearly the next step in the involvement of human presence, human intelligence and, most importantly, the human spirit, in the exploration and utilization of space. That is why it is so important that we move ahead with development of Space Station Freedom. Other nations have certainly recognized the extraordinary value of the experience of a permanent human presence in space; the Soviets assuredly have acknowledged it and have already committed major resources to bring it to fruition. Without the space station, this Nation would need to reexamine fundamentally its goals and objectives for the civil space program.

Space Science and Applications

Nearly $2.0 billion of the budget request for FY 1990 is planned for the Research and Development activities managed by the Office of Space Science and Applications. These important activities are, of course, directly supported by other elements of the NASA program - particularly Space Transportation and Tracking and Data Acquisition.

For more than 20 years, the Space Science program has been extending our vision and expanding our understanding of the solar system, the galaxy and the universe, and it has given us a new way of looking at and understanding the Earth. Only from space can we observe the Earth on a global basis.

The Science program is on the verge of a new era with the resumption of flight activity on both the shuttle and expendable launch vehicles. By the end of 1990, we will have launched the Magellan mission to Venus, the Galileo mission to Jupiter, and the Hubble Space Telescope, the first of the Great Observatories. In addition, we will have launched the Gamma Ray Observatory, the Cosmic Background Explorer, the ROSAT, and the Ulysses mission to look at previously unreachable areas of the sun. We will have flown an important Life Sciences Spacelab mission. We will be developing the mirror for the Advanced X-Ray Astrophysics Facility (AXAF) and instruments for the Global Geospace Science mission. The FY 1990 budget proposes initiation of the Mariner Mark II spacecraft missions (CRAF and CASSINI) to expand our knowledge of comets and of Saturn and its satellites. CRAF/CASSINI will study the material from which the solar system formed, the material from which life formed, and the chemistry which gave rise to that life.

The Applications program applies space capabilities to the Earth and its environment, to materials processing, and to communications and information systems. More than $400 million is proposed in NASA's FY 1990 budget for spacecraft, instruments, research and analysis relating to our Earth's environment and climate. Development of the Upper Atmosphere Research Satellite will be nearly complete, and we will be well underway on our portion of the international TOPEX Poseidon ocean monitoring satellite. We will be defining the next major Earth Observing System. The proposed budget provides for continued development of new equipment and experiments to take advantage of the microgravity environment. The space station microgravity environment offers a unique promise for research and development in new materials, medicines, and processes which are beyond our present capabilities on Earth.

Aeronautics

For our Aeronautical Research and Technology program we are requesting $463 million in the Research and Development program. This may well be the portion of our budget that yields the highest early return.

Since the early days of aviation, the technology developed by NASA and its predecessor - the National Advisory Committee on Aeronautics - has been a major factor in the preeminence of this Nation in atmospheric flight - both in military aircraft and in civil transports. Today, the aircraft industry is the leading contributor to our balance of trade, providing a positive contribution and a favorable balance of $16.8 billion last year. Eighty-six out of every hundred civil transports in the world today were built in the United States. More than a million Americans earn their living in aeronautics. Clearly, our Nation is the world leader in aeronautics. We need to keep it that way.

Our FY 1990 budget covers a comprehensive program of aeronautical research and technology to:

-- address the critical issues associated with the U.S. air transportation system;

-- enhance U.S. competitiveness in the international market place;

-- preserve our preeminence in aviation for the security of the Nation.

We will be focusing on technologies to enhance aviation safety, efficiency and performance across a broad range of vehicle applications. We will begin a new thrust in high-speed research with emphasis on the critical environmental issues of atmospheric impact, sonic boom and airport noise.

Our future place in world aviation depends on the research and technology work we do now.

Transatmospheric Research and Technology

The FY 1990 budget includes $127 million for NASA's share of the National Aero-Space Plane program effort to develop the technology to take us beyond present atmospheric flight capabilities into the realm of hypersonic, transatmospheric flight. NASA efforts are aimed at accelerating development of the critical materials, propulsion and control technologies which could enable a new class of vehicles in the future capable of flight to orbit as well as hypersonic flight between points on earth.

Space Technology

For FY 1990 we are requesting $338 million for Space Research and Technology Activities. It is now taken for granted that man can fly into space, conduct exciting missions, see deep into the universe, observe the Earth as a global system, and watch events around the world in real time on our television screens. A lot of hard work in space research and technology over many years has enabled these capabilities. But, continued focused effort is required to realize future possibilities -- not only in space, but also to maintain and expand the Nation's technological base.

We have drawn heavily from technology developed in the past. NASA is working on technologies for the future, but the many knowledgeable groups which have reviewed our program have been essentially unanimous -- we need to strengthen our efforts.

We are moving to do that:

-- NASA's basic program explores fundamental technology in newly emerging areas which offer promise of longer-range, high-leverage benefits.

-- The Civil Space Technology Initiative focuses on the technology needed to enhance our near-earth capabilities including automation and robotics, information systems, propulsion, power, and large structures in space.

-- The Pathfinder program is developing new technologies needed for potential expansion into the solar system - major studies include surface exploration, in-space operations, humans in space, transfer vehicles, and mission studies. Our mission study activities focus on possible future human exploration out into the solar system. The studies are examining mission design options including possible use of the Moon as an observatory base or for using lunar resources at a Lunar base, or possible piloted missions to Mars and its moons.

-- Finally, a new thrust is included to extend technology development to in-space experimentation using the shuttle and ELV's now and, later, the Space Station Freedom.

Space Operations

None of our space flight programs could meet their objectives without the availability of high quality, reliable space operations tracking and data support. Our FY 1990 budget includes $1.1 billion to assure that support now and in the future. The transition from a ground-based tracking network to a space-based system for low-Earth orbit missions is continuing with the launch of the next Tracking and Data Relay Satellite (TDRS). The budget continues this activity including replacement of the TDRS lost in the Challenger accident to ensure continuity of service through the mid-1990's. The budget includes procurement of equipment for a second TDRSS ground terminal which is critical in order to eliminate the present ground terminal as a single point of failure, and to provide the capability of operating more than two TDRS in orbit, as well as it being important to future system operations and reliability. The budget also provides for operations and improvements of the Deep Space Network to support the upcoming planetary missions.

Commercial Programs

The FY 1990 budget request includes $61 million for the activities of the Office of Commercial Programs. During 1988, agreements were completed to fly the Spacehab microgravity facility on the Space Shuttle and with the University Corporation for Atmospheric Research to use the Space Shuttle external tanks. NASA also signed launch support agreements with several expendable launch vehicle manufacturers. The FY 1990 budget provides for continued improvement of the Technology Utilization Network System which facilitates timely and effective communications among the Industrial Applications Centers, the Technology Counselors, and other NASA Technology Utilization offices. We plan to establish links with other networks in FY 1990. The budget emphasizes the development of ground facilities and equipment to expand the NASA technical research data base used by the private sector. The FY 1990 request also includes funding for support of sixteen Centers for the Commercial Development of Space.

Safety, Reliability, Maintainability, and Quality Assurance

The FY 1990 budget request of $23 million supports the aggressive implementation of the NASA Safety, Reliability, Maintainability, and Quality Assurance program. This effort will pursue the strengthening of the execution of NASA programs through continued introduction of systems to provide Agency-wide independent assessments, problem reporting, failure analyses, corrective actions, trend analyses, in-depth safety reviews, and nondestructive evaluations.

University Space Science and Technology Academic Program

This new budget line item of $35 million provides for continuation of Agency-wide university and minority university programs previously budgeted in other NASA programs. FY 1990 funding will support graduate and undergraduate student fellowships, faculty fellowships, the historically black colleges and university research program, other minority universities, and the Space Grant College and Fellowship program.

Private Sector Investment and Involvement

An important thrust of this Administration's policy and the FY 1990 budget is increasing the participation of the private sector in space -- not simply in performance of work, but in financing new activities and in accepting some of the risks, as well as sharing in the benefits. In accordance with the National Space Policy, the FY 1990 budget encourages greater private sector involvement in meeting the Nation's space goals. During the coming year, one of NASA's major efforts will be to seek increased private sector investment and involvement in space.

With respect to the planned space infrastructure, we have identified, as candidates for private investment, portions of the development of extended mission duration capabilities of the Shuttle; the development of the space station Flight Telerobotic Servicer, solar dynamic power, and a docking module for the Space Station, and future requirements for the Space Station, including those under study. The budget plan includes Government use of a commercially developed space facility (CDSF), with funding beginning in 1992. In ground-based facilities, the proposed budget includes seeking private financing for facilities for processing the space station, for neutral buoyancy training of space station astronauts, and for R&D on observational space instruments. NASA will develop specific procedures and criteria for commercial development of space-related systems including the space station and other manned space flight systems.

Timely success in this endeavor is essential to allow the program to work within the proposed budget level; it is crucial that NASA be in the best position possible to explore private opportunities in a timely fashion, so these vital elements of the Space Station program and important Shuttle improvements can move ahead on schedule. It is important that Congress act quickly to consider NASA's proposed FY 1990 authorization bill, which will be transmitted to Congress in the near future, and will address the issue of termination liability for private sector investment in these critical areas.

NASA Capability

A major priority of the FY 1990 budget request is the continued assurance of the health and strength of the NASA institution, on which the Nation has relied so heavily for nearly thirty years. The FY 1990 budget proposes $341 million for Construction of Facilities and $2.032 billion for Research and Program Management. As you know, Research and Program Management funding provides for our civil service personnel - the researchers, scientists, engineers and managers - for their travel, and for the basic operation of the NASA institution. The key element in all NASA programs - past, present and future - is, in fact, our people. The budget proposals for 1988 and 1989 recognized the need to revitalize and invigorate the NASA workforce and facilities. The 1990 budget continues this thrust.

While I believe that NASA still has a superb work force, possibly the best ever assembled, the Agency must work constantly to keep it that way, with a focus on quality and on the needs of the future. We need to balance our experienced scientific and engineering work force through people with new ideas and concepts. The Nation's future in space and aeronautics depends on a dynamic, competent core technical capability at the NASA centers. At the same time, NASA must strengthen its management capabilities - the ability to deal effectively with highly complex program engineering and integration requirements involving activities throughout this country and abroad. In addition, NASA must provide appropriate facilities and equipment commensurate with our research and development objectives.

Therefore, the proposed FY 1990 budget reflects as a high priority the necessary funding for people and facilities. The Research and Program Management budget provides an increase of 700 people over FY 1989 level. NASA needs those people, and we intend to acquire the best people available to meet NASA's needs now and in the future. The Construction of Facilities budget request accommodates critical requirements supporting the Space Station Freedom program, necessary space flight improvements, advanced aeronautical research and the Aeronautical Facilities Revitalization Program.

Summary

In summary, the FY 1990 budget request approved by President Reagan proposes the following:

Research and Development	$ 5.752	billion
Space Flight Control and Data Communications	5.140	billion
Construction of Facilities	.342	billion
Research and Program Management	2.032	billion
Inspector General	.009	billion
TOTAL	$13.274	billion

I believe that this FY 1990 budget proposal reflects the fact that the space program is back on track. The content of NASA's program is solid, productive and exciting. I must caution you, however, that this is a very tight budget. NASA can only accomplish the objectives, and the programs outlined, if it has full support all the way through the process. We are prepared to give it our best shot -- and we are counting on the support of the Administration, the public, and especially the Congress.

Senator GORE. Well, thank you very much, Dr. Fletcher. I want to congratulate you on that statement.

We are going to use a ten-minute rule in asking questions, and I will ask the staff to keep the clock.

Dr. Fletcher, NASA requested $14.3 billion from OMB for fiscal year 1990, which included approximately $14 billion for ongoing NASA activities and $300 million for new activities. However, the budget submitted to Capitol Hill is only for $13.3 billion. That is a reduction of $1 billion from the original NASA request. You referred to this as a very tight budget, despite the fact that NASA would get an increase.

Now, with the budget request being so much less than NASA's own internal current services runout for the programs approved in FY 1989, would it not be more appropriate to depict this budget not as very tight, but as inadequate?

Dr. FLETCHER. Well, in a sense it is inadequate. We cannot do all the things that we said we were going to do last year when we had to cancel some programs and slow some other programs down, all of them important programs. So, you can call it inadequate or marginal or submarginal. It is not what we need.

Senator GORE. So, inadequate would be an accurate adjective?

Dr. FLETCHER. That is one way of putting it, Mr. Chairman.

Senator GORE. Is it a way that you would endorse?

Dr. FLETCHER. I think that I would say marginal to submarginal.

Senator GORE. Well, NASA's runout for fiscal year 1990 to continue ongoing activities is $14 billion in fiscal year 1989 dollars, correct?

Dr. FLETCHER. That is correct, Mr. Chairman.

Senator GORE. Well, inadequate seems to me to be accurate.

Now, let us talk about this insistence by OMB that you find private financing for some of the projects that are part of NASA's program. One example is the flight telerobotic servicer. How are you going to find private financing for the flight telerobotic servicer?

First of all, by way of background, the flight telerobatic servicer is beyond the state of the art—it is an innovative, cutting edge technology development program that is required to build, a robotic instrument that will service the space station and its components, that are either arriving at or leaving from the space station.

It has never been done before; the technology is new; and it is high risk; It is going to be used in orbit, and yet OMB has said that this would be privately financed. Is Nabisco going to finance it or KKR? Is it going to be a leveraged buyout? Where is the private financing for this telerobotic servicer going to come from?

Dr. FLETCHER. Mr. Chairman, you picked out about the worst case.

Senator GORE. That is just a coincidence.

Dr. FLETCHER. The honest answer is we do not know at this point. We are still in discussion in OMB on how we can do this. It is a very highly technical program. It is probably one of the most highly sophisticated programs that we are involved in at NASA.

We did not agree that it could be. We agreed to try and do it, and at this point we really have not resolved how we are going to get a company to sign up to do that.

It is rather complicated, Mr. Chairman, by the fact that we have two contractors that had been bidding on this as a government-financed program, and they have already sent in their bids, and we are in the process of evaluating them. I think March or April is the timetable for source selection, and we have got to figure out how we deal with them on this privatization issue. And so far, quite frankly, Mr. Chairman, we have not come up with a solution to that problem.

Senator GORE. Well, I think that is a very serious problem because, Dr. Fletcher, among all the people that I have had a chance to work with during the 13 years that I have been on Capitol Hill, I do not think I have ever seen an administrator who is a better budget person and who can more accurately track what is possible and what is available than you are.

When you say it is just not possible, it is not possible because you have tried everything. And I think that although this may be the worst case, it is far from the only case.

The third-party financing has been assumed not only for the telerobotic servicer, but the extended duration orbiter, the advanced solid rocket motor production facilities, the space station processing facilities, the space station docking module, the neutral buoyancy tank, and the observational instrument lab. We are kidding ourselves if we believe that private industry is going to step up to the plate and voluntarily finance all of these projects.

For some of them you may well be able to get some private participation—the neutral buoyancy tank is probably the best example of that. But as far as the others are concerned, I think we are kidding ourselves.

Now, let me just ask one other question on this round and then I'll turn to Senator Pressler.

We are in the midst of a global ecological crisis that is without any precedent in history, and NASA is going to play a key role in improving our understanding of it and helping point the way to solutions.

One aspect of this crisis in addition to global warming is the depletion of the stratospheric ozone layer. An emergency expedition is soon to return from Norway and the Arctic to tell us of their findings there. We are desperately in need of improved information about the distribution of ozone in the stratosphere throughout the globe, and yet NASA has, according to my information, cancelled the plan to fly the total ozone mapping survey instrument on the Earth probe mission. Why was this critical scientific experiment bumped?

Dr. FLETCHER. Mr. Chairman, that program was extremely important. We call it TOMS, for Total Ozone Mapping Survey. We do have an instrument which is the TOMS instrument, which is an ozone measuring instrument, and it is planned to go on at least one Soviet vehicle.

Senator GORE. Let me get this clear. We cancelled it on our vehicle and we are negotiating to try to get it on a Soviet spacecraft?

Dr. FLETCHER. The Soviet commitment had already been made before this budget was put together. So, that is ongoing and will happen and there is enough money in the budget to do that.

There is also enough money in the budget to do a similar thing with the Japanese, what we call ADEOS, and I have forgotten what that stands for, launch vehicle, and with those two programs possible, we did not terminate the TOMS mission. That was on a small expendable launch vehicle.

We simply deferred it one year because of the already ongoing possibilities with both the Russians and the Japanese. However, we are not terminating that at all. It is a good mission. The TOMS will be used over and over again on many other vehicles, and I expect we will get continuing good ozone measurements from that instrument.

Senator GORE. OMB was responsible for the decision to drop it out of the budget. Is that correct?

Dr. FLETCHER. Yes. They asked to defer it. I do not believe they asked us to cancel it. They asked us to defer it one year because they knew about these other programs.

Senator GORE. Okay, I will pursue other questions later. My time has not quite expired, but I want to move on.

Senator Pressler.

Senator PRESSLER. Thank you very much.

I have some questions from Senator Gorton to ask for the record. I will place those in the written record.

Dr. Fletcher, your budget assumes—and these are my questions, incidentally—your budget assumes nine flights for the space shuttle in fiscal year 1990. Is this realistic? And if you were not able to meet this schedule, would this result in a saving or would it merely delay the actual outlays?

Dr. FLETCHER. As I recall, there are nine. It does not save a heck of a lot of money to drop out flights because basically the cost for extra flights is on the order of $50 million per flight. Its value is more like $300 million, but the cost is only $50 million.

So, if we cannot make that schedule, and I think we can, but I would like Admiral Truly to comment on that, it would not save an awful lot of money. It would save on the order of $50 million. But I think we have a good chance of making that.

Do you want to respond?

Admiral TRULY. Senator, we do have nine flights scheduled. We are going to be bringing on new facilities to support those flights. Second, mobile launch—I mean additional mobile launch platforms and the availability of the second launch pad during that year.

And I think that we have an excellent chance to meet that manifest in 1990 as well as the manifest we are working hard to meet here in 1989.

Senator GORE. Would my colleague let me interject a point?

Is it not true that OMB has forced you to cancel one shuttle flight in 1990 and delay another one in 1991?

Dr. FLETCHER. That is correct, Mr. Chairman.

Senator GORE. Thank you.

Senator PRESSLER. And anything further that you want to submit on that issue and also on how much money is saved or not saved by cancelling a flight would be approached.

We sometimes get different estimates from OMB than we do from you, and I do not want to start a fight here, but that is something that I want to follow up on this year. I tend to agree that cancelling a flight really does not save that much money if we are set up on an incremental basis. But I would welcome additional expansion on that.

I am concerned about your ability to attract and keep engineers and scientists that are required for a robust program. This is something I have always had an interest in. I understand that a large percentage of your professional employees are nearing retirement. Is NASA prepared for the retirement of all these people? Do you need to improve your recruiting? What legislation will be required? What can we do to help?

Dr. FLETCHER. Senator Pressler, you have hit on a very sensitive point with us. After the somewhat embarrassing, for us, anyway, action by the Congress on this pay raise bill, we——

Senator GORE. That is out of order, Dr. Fletcher.

Dr. FLETCHER. I can understand that.

Mr. Chairman, as you know, I am on my way out, so I can speak more freely.

Senator GORE. We hope you take advantage of this burst of candor on other questions.

Dr. FLETCHER. We really are facing a problem currently, almost 70 percent of NASA's Senior Executives are eligible for retirement. Nearly 25 percent are eligible for voluntary retirement and another 45 percent through discontinued service. Furthermore, within the next 2 years the number of Senior Executives eligible for voluntary retirement becomes 37 percent of the total SES population. Looking at the entire NASA workforce, 40 percent are eligible for retirement, 14 percent of these are eligible for optional retirement, another 26 percent for discontinued service.

Now, they have stayed on, a lot of these folks, because of the accident, just loyalty to the agency and to the U.S. Government and to the Nation. A lot of them were planning to leave anyway, as soon as we got back on track with the Challenger.

Some of those said, hey, I might change my mind if we get a decent pay raise, because basically a significant pay raise would make it competitive with industry. Not real competitive, but it would make it worthwhile to stay.

When the whole thing fell through they said, all right, I am gone. So, I know a lot of people have come to me and said, all right, I will wait and see what happens, if anything, in the next several months, but I am going.

There are another group of people, however, who had not thought much about whether they were going to stay or leave, but the fact that the SES, the Senior Executive Service folks were not even being treated in this whole affair, they are saying look, if that is what they think about us, I ought to be thinking about leaving and going for a reasonable salary in industry.

And so I think we have got a desperate problem at NASA right now. I do not know what we are going to do if any fraction of that 45 percent decide to leave. We do not have the young people yet ready to fill their shoes when they leave. So, I would say the situation is close to desperate right now at NASA in terms of keeping our people and retaining or recruiting new people.

Senator PRESSLER. I would welcome you to submit additional data for the record.

I want to move on to—following up on a question of Senator Gore's—the global change issues. I would like to ask how much funding in this budget is allocated to global change research. How do you see that expanding in the next five years and perhaps most importantly to me, how will the EROS data center near Sioux Falls, South Dakota, fit into the overall NASA global change research effort?

Dr. **Fletcher**. Well, global change or global climate, as it is sometimes called, is a very high priority in NASA, and we have quite a large number of programs already. It amounts to $400 million worth of programs in the fiscal 1990 budget.

On the other hand, we expect to expand that program. So, it is important because the space element of measuring global change is probably the most critical element. When you are talking about global things, space is the best way to do global things.

In terms of the effort, it is really across the government. There are a number of agencies besides NASA involved. The NOAA, National Oceanographic and Atmospheric Administration has a role, particularly on the remote sensing of weather, and they also have the responsibility for funding the remote sensing of land, the so-called Landsat as we used to call it.

However, the Department of the Interior also has a role. In the early days it was quite clear that the Department of the Interior used these Landsat data for some of their geodetic work, and it turned out it was a useful thing to distribute, for them to distribute the Landsat images and also the Landsat tapes, the data that's recovered, and so these three agencies plus the National Science Foundation are all involved in global change.

Now, we used to call it the EROS data center—I do not know whether we still have that name—in South Dakota it is still funded primarily by the Department of the Interior, but also partially, as I understand it, by NOAA. NASA has no responsibility for that, but we think it is an awfully important part of the global change program.

Senator **Pressler**. I would welcome you to submit additional comments on that as you go back to your office and look into that. I think it would be a national tragedy if we were to lose the archives and the pictures that are there because they are not being stored and they are exactly the kind of thing that NASA is going to have to have if it is going to carry out the global change requirements that have been put on it in the Reagan budget.

And I would guess that that will hold fast in the Bush budget. Thank you, Mr. Chairman.

[The following information was subsequently received for the record:]

The EROS Data Center is a part of the Earth Resource Observation Systems (EROS) Program of the Department of the Interior, managed by the U.S. Geological Survey (USGS). It is a national archive, production, and research facility for remotely sensed data and other forms of geographic information. The Center was built in the early 1970's to process and disseminate photographic imagery and electronic data of the Earth's resources, acquired from spacecraft, aircraft, and satellite sources.

The Center provides access to aerial photography acquired by the U.S. Department of the Interior, to Landsat data and to photography and other remotely sensed data acquired by NASA. The Center holds nearly 2,000,000 aerial photographs of

U.S. sites. Each year the Center processes over 60,000 inquiries and requests for information, resulting in the annual production and shipment of over 250,000 photographic products and 4,000 digital products.

Under the provisions of a Memorandum of Understanding between NASA and the USGS concerning Experimental Land Remotely Sensed Data Processing. Distribution, Archiving, and Related Science Support, NASA's Earth Science and Applications Division is planning to archive at the EROS Data Center land-related data from its proposed Earth Observing System (Eos) mission in the mid-1990's.

Senator GORE. Thank you, and let me reemphasize the comments of Senator Pressler in saying the entire subcommittee is very interested in the EROS center and the role it plays.

Senator Robb.

Senator ROBB. Thank you, Mr. Chairman.

Dr. Fletcher, I do not pretend at this point to have the detailed knowledge of some of your activities that I hope to have in the future in order to assess the budget that has been submitted and that has been modified.

As someone who has worked with budgets in the past, however, I am always interested in what falls just in or just out of the budget on the basis of the kind of priorities that you have to establish.

I do not want to alert nor do I not want to cause anyone to be concerned by the nature of the question I am about to ask because I am not contemplating major additional cuts nor am I contemplating major additional resources being available, given the constraints in other parts of the federal budget.

If you were to list the types of things that came closest to the margin with your $13.3 billion budget, could you give me, in layman terms, the types of programs that just made the $13.3 billion cut. Also, if you had the additional billion dollars that were deleted by OMB or additional funding beyond that, what priorities and programs would you establish within the agency to fund.

Dr. FLETCHER. Senator Robb, it is a lot easier to talk about the ones that we would add if we got back to what we requested.

Senator ROBB. And probably a lot more comfortable for your colleagues, too.

Dr. FLETCHER. There is a lot of agonizing about which ones to drop out. Certainly the TOMS was one that we did not want to drop out. We had to slow down the advanced solid rocket motor, which is the crucial program for the shuttle in the long term.

We had to slow down the orbiting maneuvering vehicle, which is also part of the shuttle, and also the space station. Those are ones that we would certainly add back in.

I hate to say it again, but people is what NASA is all about. Without our people we cannot really perform, and we are shorthanded. As of the beginning of fiscal 1989, we were about 2,250 people short-handed which we need to fund.

We did not get adequate funding in fiscal 1989. We are going to need a reprogramming authority sometime this year to get on the track with that increase, and we will need another reprogramming in the fiscal 1990 budget before we are through to get up to that figure.

Right now the money that is in the R&PM budget does not support the people we need. If we start going much below that, I would not begin to guess where you would begin to cut because all the programs at NASA are interrelated.

And you would be tempted to say well, you can always get by with a little less aeronautics, a little less space technology, but that is the seed corn of our future. And I do not think that is a wise thing to cut either.

It is sort of like asking a family budget—you cut way back, you have lost your job, and you have got retirement pay, and you have little kids to raise, and you ask which kids are you going to let starve to death. It is a hard one to deal with at this point.

If we are cut, the chances are we will cut all things uniformly and just slip things down the road a ways. Some things are not slippable because there are planetary windows that have to be maintained. But by and large I think that is kind of the general way we would have to deal with any cut.

Senator ROBB. You are not at the point where there would be a specific programmatic area that would take a disproportionate share of any burden that was placed upon it by budgetary constraints elsewhere?

Dr. FLETCHER. I would not, Senator Robb. On the other hand, an easy target is any new program that we have started. You can always say a new program, well, you can always wait another year. And the space station is one such project.

Other Members of the Senate and the House also have said hey, that is a good place to cut. I would not recommend that, but that is an obvious target for the Congress to make, and so that is the one that will probably suffer if there is any major cut.

Senator ROBB. One additional question. The comment has already been made about commercialization of some of the functions that you currently perform. There is significant interest in some parts of the country, and I will admit a parochial concern here, about the ability to cooperate with some private launch companies. Are there any particular policy considerations or budgetary implications that guide NASA's approach to working with those who would like to engage NASA's facilities for launches?

Dr. FLETCHER. Senator Robb, as you well know, the expendable launch vehicle part of NASA has been commercialized, and we had a rough start, but it is thriving right now. The ones that have already been under development, which are the Delta program, the Atlas Centaur program, and the Titan III program, have been transferred over to the private sector. There are a number of new programs coming along that look like they can be privatized, smaller payloads such as the Scout.

As you also know, we have provided facilities, some in your own state, NASA facilities, for those private launch companies. So, I would say in this budget I see no impediments for continuing expansion of the private launch, expendable launch industry.

These are really part of the whole privatization initiative of the Reagan administration. This isn't just NASA being singled out for these initiatives, but it is a different phase. These are, to a large extent, facilities, ground facilities, that have some hope of making a profit for private industry plus a few that were mentioned by the Chairman that are kind of tough to deal with, space portions of the program, and we are having a struggle dealing with those.

Senator ROBB. Thank you, Mr. Chairman. I will yield the remainder of my time.

Senator GORE. Thank you.

Senator Lott.

Senator LOTT. Thank you, Mr. Chairman.

Dr. Fletcher, I know that you and all of your people at NASA have expended a lot of effort and time and money in trying to get NASA back on track I believe, to use your terminology, that you have made real progress. However, the *Challenger* accident occurred almost three years ago, now. Do you feel that we really have turned the corner? Is that behind us and are we now as a matter of fact going to be not only competitive but in the forefront in space exploration with the benefits that should come from this program in so many areas?

I would like for you to be a little bit more optimistic and aggressive in assuring us that we have turned the corner. Now, first, how many launches have we had since then?

Dr. FLETCHER. Just two launches of the shuttle. We have had about five or six launches of expendable vehicles.

Senator LOTT. Let me go back to my other question. We have spent time and energy and money trying to get back on track. Are we there?

Dr. FLETCHER. No. You mentioned turning the corner. We probably have turned the corner, but we are a long ways from being back on track. We really need, I think, as properly said by the Chairman, we need to get up to the $14 billion level in 1989 dollars in order to put together a viable program. If we cannot get up to that level, we are in trouble.

Senator LOTT. You mean $1 billion makes the difference in whether we get on track or not?

Dr. FLETCHER. Yes, indeed, and $1 billion in this year's dollars and depending on what you assume about inflation, that is a little bit more than $14 billion in 1990 dollars. We have got a ways to go before we are really back on track.

Senator LOTT. I know it has been a difficult thing, a lot of reevaluation, a lot of doubling up on precautions, and that is fine. But I think there is a perception that it has, in effect, paralyzed us to some extent, and it is time to move beyond that paralysis and get back to where we were before that incident.

Let me ask you to go back over three years. Give me, if you would, with the help of your comptroller the funding numbers for NASA over the previous three years. Please include the fiscal year that we are in, not the one that we are working on. What are those numbers?

Dr. FLETCHER. Let me give you an overall concept of what happened. Three years ago we had anticipated that the shuttle cost would come down, and that while they were coming down we would have enough money to fund the space station. Well, in fact the shuttle costs did not come down. They increased substantially. Then we had the space station to fund on top of that, and that is what caused the major increase over the last three years. Mr. Campbell?

Mr. CAMPBELL. I have the FY 1988 value, Senator Lott. It was $9 billion, and in FY 1989 it is $10.9 billion. This year our request is $13.3 billion.

Senator LOTT. So it has gone from $9 to $10.9 to $13.3 over a three-year period?

Mr. CAMPBELL. Yes.

Senator LOTT. Well, I urge you to continue every effort. While we would all like to be able to provide more money, and certainly I would like to see more money in this area because I think we derive a lot of benefit from these programs beyond just having a flight into space, I think the trend is clearly up over a three-year period. A lot of programs have been static or even gone down. So I think Congress and the Administration have been trying to move forward with you, at least in a dollar sense.

Dr. FLETCHER. Senator Lott, you are absolutely right. There is just a lot of benefits from space, and we cannot begin to enumerate them here.

The *Challenger* taught us a lot, though. It taught us that we were short of people; we were using outdated facilities. We really were not paying enough attention to safety, and that means testing of some of the components of the shuttle. All of these things add up to a significant increase, percentage-wise anyway, in the NASA budget.

But still, in the overall scheme of things, as we keep reminding ourselves, the total NASA budget is still only 1 percent of the Federal budget. So up or down, the NASA budget is not going to affect the overall problem that Congress has in the deficit.

Senator LOTT. Just briefly, if you will, tell me about your university space science and technology academic programs. Is that something that is really being worked with? Is that something that we really need? Are we going to get some benefit out of that? I think it is something that we really do need to pay attention to but it is a very small part of your budget.

Dr. FLETCHER. Senator Lott, that is a new budget line item which consolidated funding of our education and minority programs. Basically it is quite clear that if we are going to have an on-going space program, not just NASA but the commercial space and the military space, we have to start training the young people.

We are going to be short of people that have knowledge about, not just space, but technical things generally, we decided in a small way—and it is very small, as you pointed out—to go ahead and set up some of these research centers, we call them technology centers, in universities; and that program is on track. It is our small contribution, if you like, towards trying to interest and excite young people for going into technical activities.

Senator LOTT. And these programs would work with NASA and universities at NASA sites?

Dr. FLETCHER. No. We implemented the initiative enacted last year—the National Space Grant College and Fellowships. These would be universities throughout the country, Senator Lott, not at NASA sites. There would be an effort to have them work closely with NASA centers so that there can be an interchange of data between the centers and the universities, but it is a nationwide program.

Mr. CAMPBELL. Senator Lott, if I could expand on that. There are really three areas of university funding in the NASA program, and NASA is requesting $5 million for the one that Dr. Fletcher addressed. There is also the University program, the academic program we call it, that is primarily fellowships and development of these centers. The funding request for that is $15.9 million. The third part is the Minority University Research program. $14.1 million is requested in FY 1990 for that program.

But we also have an engineering program that is about $17 million in the Office of Space Research and Technology in addition to this $35 million I just listed. That was initiated in FY 1988. The total funding that we place in universities throughout the NASA program is, considering the entire NASA program, is probably in the order of $400 million.

Senator LOTT. But at least in one notable instance you do have the opportunity where there is university activity on a NASA site that you can take advantage of, I believe.

Dr. FLETCHER. We are aware of that, Senator Lott.

Senator LOTT. I would not mention any names as to where it is located, but I did just want to mention that as a very good opportunity.

Let me shift, because I do not want to eat up too much of my time. I have a couple of other areas I want to ask about, but let me get to the one I am particularly interested in today, and that is the advanced solid rocket motor funding and how it is going to be funded.

Well, let me ask you this first: advanced solid rocket motor. Next generation motor for NASA. How important is that, and why must we have it?

Dr. FLETCHER. Senator Lott, it is extremely important. After the accident, we began to examine the current solid rocket motor and we do not have to go through all the gory details but we found a lot of problems with it. We fixed the major problems. We call it the redesigned solid rocket motor that is now being built by Morton Thiokol Company.

We decided that we needed to do several things to improve the situation. First of all we needed to make an arrangement whereby we could bring in new contractors when we felt that the contractor was not performing adequately, and that was one consideration.

Another consideration is that we needed a brand-new facility for building these solid rocket motors. And I hate to say it but these solid rocket motors are put together with plastics, glue and putty, and that may be an exaggeration.

Senator LOTT. I hope it is.

Dr. FLETCHER. But when you dig into it that is what it comes to. Now that is not quite fair. The rubber is a very special kind of rubber that is used as a fuel, and the liner, which has to be bonded to the interior of the case, we call a liner but it has to be bonded, and it is kind of a state-of-the-art thing, so there is a lot of risk in this whole process.

It is almost cookbook technology. We have got to get more order into the construction of the solid rocket motors, and that is why a new facility is needed.

The third thing which is not insignificant is the ASRM does give us a significant increase in payload. We began to run short of payload way back in the late 1970s, and we are supposed to have 65,000 pound lifting capability in the Eastern direction, and we are way below that. And we think that the solid rocket motor—the advanced solid rocket motor—will bring us back up to where we need to be on the payload requirements.

Senator LOTT. I believe Congress has already provided some funding in this area and you are moving forward with the program to construct the advanced solid rocket motor. Is it on track? Is it going forward in this next fiscal year, and how does your budget recommendation treat that?

Dr. FLETCHER. The advanced solid rocket motor is on track. We had to slow it down some because of the $1 billion cut that we took from OMB. I think there is about $120 million in the development part of the program for the advanced solid rocket motor.

Of course, still in question and before the House is the privatization of the facility, the new facility that is required probably on the Yellow Creek site. The contractors have submitted their bids. They are in the process of being evaluated, and I think along about April or so we will have a contractor selected.

We do need termination liability from the Congress before we can go ahead with a privately-financed facility. We have asked the contractors to bid both ways: privately-financed and government-financed, on the facility itself, but we do need termination liability in case the contractor chooses——

Senator LOTT. Let me touch on that point. I realize my time is about to expire and I know the Chairman needs to move on, but I also know he is interested in the subject matter and will give me a minute more.

You made a point that you say you need this termination liability language, and you need that authority from the Congress and you need it as early as possible in this fiscal year. Is that correct?

Dr. FLETCHER. Yes, indeed. It is going to be hard to select a contractor because we have asked them to bid both ways, both company-owned/company-operated, and government-owned/company-operated, and in order to negotiate the selected proposals we have got to have some assurance that we are going to be able to support them.

They are not going to go ahead and invest their money unless they have some guarantee that the government will finance them if the government changes its mind. So we need that soon.

Senator LOTT. Thank you, Dr. Fletcher. My time has expired. Maybe I will have another chance on the second round. Mr. Chairman, though, I would like for you to make particular note too, of this request.

Senator GORE. Oh, absolutely. The legislation on termination liability has not yet been submitted to the subcommittee by NASA, has it?

Dr. FLETCHER. That is correct, Mr. Chairman. It was felt desirable to wait until President Bush's budget was sent forward, and it will come forward shortly after that.

Senator GORE. Let me just say that I have a very keen personal interest in that solid rocket motor facility, and will be working closely with Senator Lott and other members of the subcommittee to make sure this project stays on schedule. It is extremely important to the future of NASA.

The facility is a perfect one for the project, and I think it is unrealistic—let me say for the record—to assume total private financing for this facility. Only with termination liability can you properly evaluate the proposals to have privately-financed facilities versus publicly-financed facilities.

There is no free ride in this. Private financing is kind of a misnomer in some respects, a gimmick, and this is one on the list of examples I used earlier where I think it is unrealistic. But I will come back to that later.

Senator Bryan, I welcomed you just before you came in. Let me welcome you in your presence and recognize you for whatever questions you care to pose, or an opening statement if you would care to. make one

Senator **Bryan**. Thank you very much, Mr. Chairman.

Dr. Fletcher, I, too, appreciate your candor here this morning, and I also recognize and appreciate the integrity with which you have handled this job during a very difficult time in NASA's development.

You and I had occasion to first become acquainted in a different light, when I had a different job, and I would like to go back to a couple of those areas if I may in the couple of minutes that are allotted to me.

You know that Nevada plays a critical role in the space program with the production of ammonium perchlorate. At one time we had two plants that produced it. As you know, last May one of those plants disappeared from the face of the Earth in an explosion. I would like to ask you where we are in terms of ammonium perchlorate production and if you have any concerns that we are not on track?

Dr. **Fletcher**. Certainly, Senator Bryan. I will have to refrain from calling you "Governor Bryan". Is "Governor" higher than "Senator"?

Senator **Bryan**. Certainly not on the Hill.

Dr. **Fletcher**. I am going to ask Admiral Truly to come up and give you a status report. While he is coming up, though, it is nip and tuck to be able to provide the amount of ammonium perchlorate that we need.

As you point out, one plant is operating and will continue to operate, but it does not have the capacity to supply all of the needs of the federal government, so we had to establish a new plant, which is in two parts.

One part is in Nevada, where the sodium perchlorate—part of the ammonium perchlorate—is produced, and the other part is in Southern Utah, as I understand it, where the last mixture is made into ammonium perchlorate, and that is the dangerous phase, so to speak.

Since this was a small company, we had some problems getting the financing for that new plant, and I think Admiral Truly is ready to give a status report on that.

Admiral **Truly**. Senator. I did enjoy working with you through that immediate crisis. We have made a lot of progress. The one company that was destroyed there has broken ground on a new site. Frankly, our principal problem, as Dr. Fletcher mentioned, has been arranging private financing which we are very close to concluding. It has been a long and tortuous path and we are not quite there.

We hope that we will begin to see ammonium perchlorate production start this summer, but it will have to first be qualified for the various users, not only space shuttle but Titans and other solid rocket motors for which it is used.

So the Nation is going to see a shortfall in ammonium perchlorate in 1989, even if that plant comes on as quickly as it can, and NASA has worked very closely and cooperatively with the Department of Defense. Because even though the space shuttle is the major user of ammonium perchlorate, there are many other users of it. As those negotiations have gone on, in fact because of the crucial importance of the payloads that are scheduled on the space shuttle in the next couple of years, all of our requirements have been met and I would anticipate that would be so in the future.

Senator **BRYAN**. Let me ask another question as a follow-up. As you know, the existing production facility is very, very close to Henderson's urban population that has encircled the plant's development as Southern Nevada has grown. There is a plan afoot, which I think you are very much aware of, to ultimately relocate the Kerr McGee facility outside of the metropolitan area, but still within the Southern Nevada outskirts at a place called Apex. To make that land available is going to involve some cooperation with the BLM, which owns that property. I would certainly encourage the agency to work with the sister agency of the federal government. Sometimes, as you know from our prior discussions, we do not always get that cooperation. We are all supportive of the relocation and recognize the importance of the facility. I think you told us a year ago that each one of those shuttle flights consumes 1.7 million pounds of ammonium perchlorate. So I know we need the plant.

I hope we can have your support in working out that Apex relocation, because that will expand your capacity if we can do so.

Admiral **TRULY**. Yes, sir. We are working closely on this. I believe we are working to the same goal and I understand the problems there in Henderson.

Senator **BRYAN**. We have strong local support, as you know, for that relocation, and I think the manufacturing facility as well.

Finally on that fateful day in May, there were several fatalities, it could have been much worse, and a substantial amount of property damage was sustained at a price tag of about $2 million. That is not large by federal standards. With a billion here and a billion there, I understand that those numbers pale by comparison.

But I think in terms of fairness, in terms of continuing the kinds of community support that that facility has enjoyed over the years, and in terms of recognizing the importance to the national defense effort as well as the space effort, we are talking about a reparation bill of a couple of million dollars to make whole those people who suffered property damage as a result of that explosion.

And I would certainly hope, Admiral Truly, we might have the support of the agency in recognizing the fairness of compensating those people who, without fault, woke up one morning and their lives were shattered, and many of them suffered substantial property damage.

Can we get a response as to what your position might be in supporting us in that effort?

Dr. FLETCHER. Maybe I should answer that, because all of us have been working with FEMA—that is the Federal Emergency Management Agency. The director of that agency personally visited that area, and his people have been there, but it is their responsibility and I guess so far they have not acted on it.

We certainly support your position, if it can be worked out. The people did not only suffer damage, but they were scared half to death, and some consideration it seems would be appropriate.

Senator BRYAN. Dr. Fletcher, with the greatest respect to you and your colleagues, we do not get the same kind of candor and forthright discussion with FEMA. They danced us around the proverbial daisy chain all last year. They were there perhaps more times than any of the candidates who were seeking public office last year in our state, with no honest assessment.

I recognize that the criteria for FEMA support are beyond your jurisdiction. The point remains, FEMA says we do not qualify. Someone in the federal government has to recognize that responsibility and deal fairly with those folks, and that is the point that I want to at least leave with you.

Let me shift the focus for a moment, if I can. You talked about the problem with the "careerists," the 45 percent who are staying on because of their loyalty to the agency and their patriotism to this country. I would like to follow up on a line of questions which Senator Lott began to develop.

We read a good bit these days that there are going to be shortages of personnel in the math, science, and technical fields. We see in general publications and broadcast reports that we do not compare very well in math and science literacy with other countries with whom we compete commercially and otherwise.

A lot of us recall that day 32 years ago when the Soviets electrified the world and launched that first Sputnik. The response was to put together a program to educate a new generation of technicians, scientists and engineers. And, within the decade, we were able to respond to the challenge of President Kennedy issued some four years later to place a man cn the moon and safely return him to earth.

Some of us believe that we need a similar consensus now, and I would like to get your opinion with the same kind of candor that you have shared with us previously. Are we doing enough? Do we need to do more, and are these three programs that you have outlined for us enough to keep that pipeline full?

Dr. FLETCHER. Senator Bryan, all of those are good questions, and they are close to my heart because I did come from academia in two capacities, one as a professor and another as an administrator of a university.

The problem is down at the elementary school and secondary school level. There are just, first of all are not enough well-trained teachers to inspire young people to go into math and science.

We sometimes use the expression, "numeracy" as opposed to literacy. There just is not enough, and as you properly point out, our people are not comparing well with those in other countries at the same grade level.

NASA cannot solve that problem, but we are doing what we can. We do a lot of things in trying to encourage young people to go into science and technology. We have the programs that Mr. Campbell outlined.

We also have a fairly broad program in education for the public schools. We call it a spacemobile that goes around and talks to the young folks, and if we had more spacemobiles we could talk to a lot more young people. It does make a difference. They get all interested in science and technology and proceed.

The astronauts also spend a lot of time in the public schools, and they and we regard that as a high priority, once they have flown, and I think we have some astronauts in the room that could testify to that.

Then we have supported organizations such as the Young Astronaut program, which is a privately-funded organization, but we have cooperated with them in many ways. I think it takes more than just NASA, but we are doing what we can, Senator Bryan. It is an important national problem.

Senator **Bryan**. My time is up but I would certainly appreciate it if you would expound on your answers, and I would hope that you would not feel constrained to respond just with the NASA hat. If there is something more that you feel that we ought to be doing, I think a lot of us in the Congress would be interested in that.

Thank you so much, gentlemen.

Senator **Gore**. We are going to be pursuing that area in other hearings.

Let me start the second round of questioning by inviting your attention to these budget charts. I want to get down to where the rubber meets the road, and look at what, I believe, are some very unrealistic projections that we are getting.

Dr. Fletcher, do you have this packet of graphs in front of you?

Dr. **Fletcher**. I have most of them.

Senator **Gore**. All right. Turn to the third page, which is the busiest, most complicated chart there, and let me just walk you through this and invite your comments on it.

First of all, starting at the bottom, the bottom line marked by the boxes is the current CBO baseline, correct?

Dr. **Fletcher**. That is what the CBO calls a baseline, yes.

Senator **Gore**. That is what they call a baseline; that is what the Budget Committee in the House and Senate will work with. That is the baseline from which we work.

Now, the next line up is the one with the circles; the core program. That is the CBO estimate of NASA's core program, correct?

Dr. **Fletcher**. That is correct, Mr. Chairman, and that is what we call our core program. So, we are together on that one.

Senator **Gore**. So, we are together with NASA on that. Now, that includes no new starts, correct?

Dr. **Fletcher**. I think the core program does include a modicum of new starts in each of the years beyond 1991. Am I right, Mr. Campbell?

Mr. **Campbell**. My understanding was that they did have some elements in that core program that were not in our present runout—the Shuttle C, for example, Senator Gore.

Senator **Gore**. They are in the CBO estimate, but not in the NASA program?

Dr. **Fletcher**. That is correct.

Mr. **Campbell**. That is correct.

Senator **Gore**. And there are no new starts after 1991?

Mr. **Campbell**. In the NASA program that is correct, and this is the Shuttle C and an orbital transfer vehicle and another replacement orbiter.

Senator **Gore**. Okay, now, if we are serious about having a competitive space program and if we are serious about playing the kind of role in space that President Bush and many others spoke about last year, there will have to be some new starts, correct?

Dr. **Fletcher**. Absolutely, Mr. Chairman. And we plan to make those new starts in the outgoing years.

Senator **Gore**. If you have the money?

Dr. **Fletcher**. If we have the money.

Senator **Gore**. Yes, well, that is where we are right now. Does the NASA budget, projected by the line marked by those circles, include any funding for a new orbiter?

Dr. **Fletcher**. Yes, I believe there is funding—you are talking about the NASA runout or the CBO?

Senator **Gore**. The NASA runout.

Dr. **Fletcher**. The NASA runout is not on this chart. The NASA runout is simply the runout of the current programs. And we have furnished that to you and——

Senator **Gore**. Right, and it is nearly identical with this line here.

Mr. **Campbell**. On the front end it is close, but the content is slightly different, the phases.

Senator **Gore**. The dollar values are nearly identical but the content differs, correct?

Mr. **Campbell**. That is right.

Senator **Gore**. So the line looks the same.

Now, does the NASA runout contain any funding for a new orbiter?

Mr. **Campbell**. No, sir. We do have, I just want to point out, in our runout about $500 million for structural spares which could be applied to reduce the cost of another orbiter.

Senator **Gore**. Does it contain any money for an Earth probe program?

Mr. **Campbell**. Not in this runout.

Senator **Gore**. Does it contain any money for a Shuttle C?

Mr. **Campbell**. No, sir.

Senator **Gore**. Does it contain any money for a Titan IV for the Earth observing system?

Mr. **Campbell**. No, sir.

Senator **Gore**. Does it contain any money for a crew emergency rescue vehicle?

Dr. **Fletcher**. No.

Senator **Gore**. Does it contain any money for the instruments for the Earth observing system?

Mr. **Campbell**. No, sir.

Senator **Gore**. Does it contain any money for a lunar observer?

Mr. **Campbell**. No, sir.

Dr. **Fletcher**. There is money, depending on how things go, there is a backup observer for the Mars observer and to the extent that that can be used for the lunar/polar observer, if we do not need it as a backup for the Mars observer, that is partially funded, Mr. Chairman.

Mr. **Campbell**. Let me clarify that, Dr. Fletcher.

We had originally a second unit for the Mars observer, but the result of the budget constraints, we have reduced that to systems spare. So you are right, we do have some systems spares that could be applied, but we no longer have the alternative program.

Senator **Gore**. All right.

Does it contain any money for a Lifesat?

Mr. **Campbell**. No, sir.

Senator **Gore**. Does it contain any money for the next great observatory, the SIRTF?

Mr. **Campbell**. No, sir.

Senator **Gore**. Does it contain any money for the estimated lease cost of the proposed third party financing initiatives?

Mr. **Campbell**. Yes, in some cases it does, Senator Gore.

The OMB provided some residual funding in the extended duration orbiterline, and in the FTS line, that could be applied to lease payments.

Senator **Gore**. If you totalled your estimates, your internal estimates of the lease costs of the proposed third party financing initiatives, what percentage of that money is provided in the runout?

Mr. **Campbell**. Well, the runout only runs through 1994, so that it is a very small percentage of the total. The adjustment is about $750 million. It was reduced, and it is about $40 million or so of lease costs that were provided.

Senator **Gore**. Okay, now, the point that I am leading up to is, with a few minor partial exceptions, all of the things that I have listed are left out of the runout. We have not even mentioned the large, new initiatives that most people believe are necessary if we are going to reestablish America's preeminent role in space. This budget does not even provide enough funds to meet the challenge of today's ongoing requirements, let alone, the challenges of tomorrow.

Now, moving up the graph, let us look at the next line. And when I am going up, I am going to the right hand side of the graph; the left hand side is a little busier.

On the right hand side, the next line up is the one marked by the deltas pointing to the right. This is a line of projections by the American Institute of Aeronautics and Astronautics, correct?

Dr. **Fletcher**. Yes.

Senator **Gore**. Now, you can see that within a few years the gap between their idea of what we should be doing and OMB's and NASA's is, in the order of $5 or $6 billion annually, growing to a spread of $7 to $8 billion annually toward the end of the century, correct?

Dr. **Fletcher**. That is correct, Mr. Chairman.

Senator **Gore**. The budget runout of the National Commission on Space, often referred to as the Paine Commission, is marked by X's. And you can see the difference there between NASA's runout and the Paine Commission projection is extremely large.

Then at the top of the graph, we have the Ride Report which listed for us two options. Those who look to the future of the American space program talk about two general options: either going back to the Moon in a sensible program of exploration, or going to Mars or one of the moons of Mars. If we took either one of those options, the gap would be absolutely incredibly large.

Now, move back toward the left hand side of the chart and look at 1992. You can see the differences already in 1990, and in 1991. But in 1992, if we were going to choose any of the new starts that put us on a more ambitious schedule, or that move us toward a more ambitious agenda in space, then there would have to be a dramatic change.

So, the question really is, whether we are serious about space, or not. The current CBO baseline would mean that we would fall backwards; we would retrench; we would retreat. We would, essentially, stop playing a leadership role in space, even as the Europeans, the Chinese and Japanese are joining the Russians in moving forward.

The Bush Administration will determine the answer to the question as to whether or not we are serious in space. But we have to be realistic. If we continue along the path suggested by OMB's instructions to you in this budget year, then it constitutes an American retreat from space exploration. We have to shed our illusions and be realistic about it, because times have changed. If we chose the Ride Report and chose the goal of going back to the moon—if the President of the United States announced today, as President Kennedy did in 1961, that within 10 years we are going to put human beings on the surface of the moon and bring them back safely—could we do it in 10 years?

Dr. **Fletcher**. Mr. Chairman, that is a judgment question. The first thing, of course, as you point out, we would have to have the money to do that.

I am not sure the Congress and the White House can act that fast any more. I hate to say this, but——

Senator **Gore**. If we set out to do that same thing we did in 1961 again, I have heard people in NASA say privately we could not do it today. Ten years to the moon and back; we simply could not do it. Do you agree with that?

Dr. **Fletcher**. Honest answer, I think it would be very difficult in today's environment. It is not just NASA, but it is all of the various restrictions that have been put on us, the constraints, the deficit and so forth. It would have to be a major national commitment, in order that we could do something like the Apollo in the 10 year period that you are talking about. Now, that is a personal view. I am not sure that is shared by my boss, but I am outgoing again, I can speak frankly.

Senator **Gore**. We appreciate the candor, but it is an incredible statement that we could not again, in this decade, in the coming decade do what we did in the 1960's with the current state of our space program.

Well, my second round questions have run overtime and I apologize to my colleagues.

Senator Rockefeller is returning to the subcommittee and we welcome you.

Senator **Rockefeller**. Thank you, Mr. Chairman, I yield to Senator Robb.

Senator **Gore**. Senator Robb?

Senator **Robb**. Thank you, Mr. Chairman.

I asked Senator Rockefeller if I could just ask one question? I have to depart but you are dealing with some major areas of priority that obviously are of concern.

I want to make sure that I understood the implications of a figure that you cited early on with respect to eligibility for retirement.

You cited the figure 40 percent as the number of those NASA employees eligible for retirement within the next two years. Is that a condition that is significantly different than the total NASA personnel picture has been over the past few years? Are we aging much more rapidly? Or is that fairly close to the picture that any agency, if you simply look at eligibility and not projected retirement dates? Are you telling us that there is a high likelihood that a significant percentage of that 40 percent will, in fact, retire in the next two years?

Dr. **Fletcher**. Senator Robb, that is a complicated question. And let me do my best to answer the various pieces of it.

NASA is, in fact, different from other agencies in several respects. One is that we have had a RIF program in the late 1970's, and early 1980's, which has pulled our manpower down and that is why we are trying to get back some of that manpower with this 2,250 people I talked about.

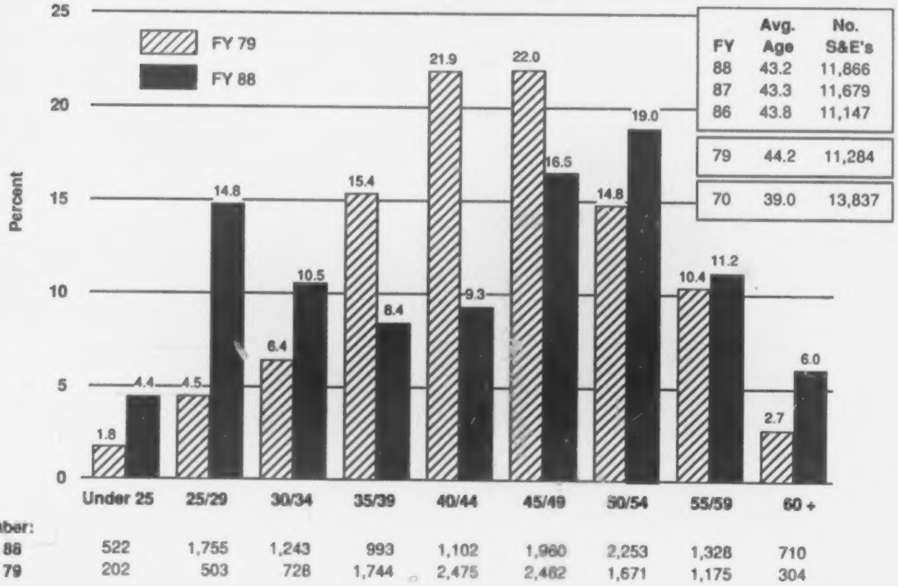
But, of course, they are younger people and so we do have, at the top end, an aging work force. So, that is one difference between us and other agencies.

The other difference is that a fair number of those people hung on for an extra three years, if you like, because of the accident—just plain loyalty. And so, they said, we are now flying again, maybe it is time for me to go find a better financial remuneration. So, we are different in those two respects.

So, we have in NASA—we can submit it for the record, if you like—a funny age distribution: we have some younger people just beginning to come into the work force, and then a dip, and then some older people ready to go out. And the in between people that have to fill the shoes of the ones that are leaving are just not in place yet.

[The following information was subsequently received for the record:]

Age Profile of Scientists & Engineers
Permanent Employees
End FY 79 - FY 88



Dr. Fletcher. Maybe Dr. Hinners would like to elaborate on that, but that is kind of a rough picture of where we are and why we are different.

Dr. Hinners. I agree that is the crux of the problem: that we are challenged both to try to retain some of those older people, who, indeed have the experience. And also try to fill the middle ranks, the dips of that curve.

Of additional concern is, retaining those people who have recently joined NASA. We are finding it increasingly difficult to recruit people, the best people into our entry level. But we are also starting to see some worrisome signs that after they have been with us three, four or five years, a few, not a lot yet, of those best are indeed leaving.

And with the new Federal Employees Retirement System it is easier for people now to leave the government, and carry their pensions with them.

So, we have either an actual or potential recruitment and retention problem across every part of the age spectrum in the agency and we will be looking for some help from the Congress with such things as the Alternative Personnel System or demonstration projects to help us solve that problem.

Senator Robb. Is it a fair assumption to make that the salary question alone would not stem the tide in a significant way with those eligible for retirement, but that it has to do more with the timing situation which is significant? And it is essentially a one-time problem because of the special circumstances that Dr. Fletcher related?

Dr. HINNERS. There is that aspect of it, Senator, you are absolutely right. But our best bet to recruiting and retaining good people is to have an exciting national space program. That is where it really is. That is why people come to work for NASA.

Senator ROBB. Dr. Fletcher and Dr. Hinners, I understand that and I thank you.

Senator Rockefeller, I thank you for yielding.

Senator Gore, I thank you.

Senator GORE. Senator Rockefeller?

Senator ROCKEFELLER. Thank you, Mr. Chairman. I apologize for being late, Mr. Chairman and Jim Fletcher.

And I know that some of these things have been covered before, but it is obviously on everybody's mind. There is an article in the Washington Post this morning, which said you have to advertise for a year to recruit a space scientist. And that the National Institutes of Health cannot lure senior researchers from the outside. So, the Congress votes down the pay increase primarily looking at our own situation and it affects many other lives. Who are you going to lose and where are their replacements going to come from?

Dr. FLETCHER. I hope you do not expect me to name names.

Senator ROCKEFELLER. No.

Dr. FLETCHER. There are a number of people that have come to me and said—in fact, if the pay raise did not go through—they intend to retire. And they are in fairly key positions throughout the agency. This is at the other end of this hump that we are talking about, the older people.

Now, we are not ready quite, to replace them. We had hoped that they would stay on a little bit longer. On the other hand, there is another group of people that have not really said they were going to leave, but are a little discouraged about the situation and say, maybe I ought to think about taking a job outside of the government, where I can be appropriately rewarded. I have stayed and I have not thought about leaving, but if this is the way it is going to be, maybe I ought to try something else.

And those people have not firmly told me, I am going to leave. But I think they are hoping for some change for the better and in a few months, I expect they will.

Senator ROCKEFELLER. And then once they start looking, the word gets around and it is a stream that picks up other streams and you have a morale problem.

Dr. FLETCHER. It is a disastrous situation, Senator Rockefeller. I wish I knew the extent of it, because it has only been a couple of days, but morale is pretty low among both the young people and the older people at NASA.

Senator ROCKEFELLER. It is an interesting phenomenon in our country, is it not, that we can take such strong actions following public opinion, reflecting our own opinion and then in so doing, willfully gutting some of our best people in government.

According to a poll taken last year, only one percent of the graduating class of Yale University was interested in going into something called the public sector, which would either be political or working for government, working for states, working for counties or cities? Yale, among the Ivy League schools, has always struck me as one that has an ethical basis—it teaches social responsibility.

Their law school does not do the case-by-case method, as they do at Harvard, but they teach that lawyers have a responsibility to better society and Yale is meant to be that way. So they have already made their judgment. I mean, they are not even in the sector yet, but they are not going to come your direction.

And we have an extraordinary ability in our country to punish ourselves, just at a time when others are getting smarter with greater emphasis on technology, math, science, we go the other direction.

Now, there is something called the University Space, Science and Technology Academic Program. And in theory, that should be beneficial in terms of attracting graduate engineers and faculty members into your program.

Can you describe, at least up until this point, some of the benefits of that program?

Dr. **Fletcher**. I would like Mr. Campbell to expand on that, because it is more than just one program. It is a series of programs, but it is our small attempt to bring more qualified people into the science and technology work force, which really in my opinion is the future of this country.

It is a national problem and we are doing what we can in a variety of ways to bring them along, to get them interested in science and technology to begin with and then somewhere along the line—and we will have to have the help of Congress and the White House on that—we have got to make it attractive for them to work in the government, and the pay raise problem is only a part of the problem.

It is the whole environment—the environment of the federal work force. But we are doing what we can at the lower, at the elementary and secondary school level, to attract young, qualified people into the science and technology programs.

Mr. **Campbell**. Senator Rockefeller, we set up, as you can recognize this year, a new budget line item on the university affairs programs to give it more emphasis, and we increased it about $13 million despite the overall budget constraints, and we did that.

We formerly funded this in the other elements of the NASA budget, but this year we focused it as a budget line item to take advantage of the management we have in place and to give them full control over the funding, and those funds are directed primarily toward fellowship programs. Getting minorities and other students focused on the technology areas in the colleges.

In addition, we have a space engineering university program, in the research—OAST program office—funded this year at about $17 million, and that emphasizes the collaboration with the agency on experimentation in space. They actually develop ideas that we will exploit in space, and it stimulates them from that standpoint.

And I mentioned earlier that overall, in the NASA budget, drawing on all of the program offices and their direct contacts and contracts with the university community, the value—that our estimate is about $400 million of this budget will be applied to that area.

Senator **Rockefeller**. Mr. Chairman, I guess I want to express frustration at ourselves, not for the way we voted but for the condition of our country on this, and then maybe some optimism at the end.

NASA is incredibly important. We are so sensitive in this country to failure, that we will go to any lengths, and probably properly so, to avoid that. The *Challenger* accident traumatized us. People stayed on at NASA perhaps longer because they felt they had to. It was fundamental loyalty. They might not have otherwise.

But where you have a situation where people hold public life in such low esteem, and probably politicians the most of all so, people do not realize what they are losing, whether it is the National Institute of Science and Technology, the National Science Foundation, or radio astronomers that work for the government as opposed to some private corporation.

I can remember when I worked for the Peace Corps. I recruited for a while. I was in my early 1920's, and I went out to a college in Arkansas, Arkansas A&N. It was all black, had no funding whatsoever, the school was rundown, and I went out there to recruit for the Peace Corps and did my job. My next stop was at Harvard University, and I did my recruiting for the Peace Corps there Arkansas AM&N left Harvard in the dust with respect to signing up and joining the Peace Corps.

I don't know whether it is this age of greed that we have gone through, but I have often felt that the most important thing that happened in the last five years was certainly not the Iran-Contra scandal but the Ivan Boesky situation. That really got at the moral fiber of the elite people in this country. And by that I do not mean by wealth but by education—people who are trained and who ought to think of public service, of working for NASA, of working for the National Science Foundation, of working for the facility out at Gaithersburg. And I do not know how we turn this around. There are more people who are studying foreign languages. That is not a government program edict.

It is beginning to happen. There are more people—and higher quality people—who are deciding to go back into teaching. This may be some kind of a turnaround.

There is a lot of talk, as the Chairman knows, in the Congress and I think elsewhere of some kind of a national service corps. I myself think that we ought to reintroduce the draft—conscription.

I think it is the elite people in this country who make the decisions. Whether John Tower gets in or does not, he is elite, he is trained. And you better have the sons, and the daughters for that matter, of those people in there, because that means that they are able to make more intelligent decisions.

I pray that the sense of public service is coming back. We are never going to be able to catch up with private sector funding. That is not going to happen. If any program ought to be able to retain people it is NASA, because that dream is alive.

I had never been to a shuttle launching, and I went down with J. McBride, who is going to command a 1990 shuttle launch with a crew of seven people. The launch was delayed and in some ways it was more interesting because I learned more about what the problems are, what causes launches not to take off.

But I can remember going the night before to look at the shuttle lit up on its launch pad, ready, and it is a temple. It is almost—without being gooey about it—a kind of a religious experience for someone who has not seen it before.

It is a temple to American ingenuity, American creativity and American technology. And there it sits, and we were right up against it. We were able to get inside the gates, which I could not have done if I had not been a senator.

It makes you aware of what this country does, and not everything is done by the private sector. I do not know what it is that we have to do to get people to understand that not everything in this world is making money. I know that is easier for me to say than for some others because mine was made for me, and I love my great-grandfather as much as any man in this world, but it is really disturbing, and it makes me angry. I'm not going to blame it on anybody. I think the last eight years have not helped dispell this idea that you make money, that you make it as fast as you can.

The Washington Post reported a year or two ago on a study of this on some students at Bethesda High School. Chairman Gore, you may remember it. And their answer was "I want to make money and I want to make it as fast as I can." And they are the elites. They are the brain elites.

So they go to Wall Street. I was overjoyed when 50,000 people were laid off on Wall Street. Let that be a lesson. Look at the long term as well as the short term, look at the public interest as well as the private interest.

Now, I am on the Commerce Committee and I recognize that we are having a NASA hearing and I am not being very helpful to either you or your budget, but I can talk about whatever I want to and that is what I want to talk about.

So having said that, I have a question about the Japanese and the Chinese getting into space—good grief, when the Japanese start getting into this we will have a lot to be worried about. What possibilities are there for privatization that will help out?

Dr. **Fletcher**. Well, I think in NASA, Senator Rockefeller, there are limited opportunities, and we have tried to define those that seem most likely to succeed the best we can. The Chairman has indicated one that is going to have problems: the flight telerobotic servicer.

But we do have four ground facilities that have real good possibilities for private financing. It has to be a situation where they gain something by their investment, but we also get what we want, and there are four ground facilities, as I recall, that fit that category. The tough part is to privatize the space activities, and there are several in that category. The flight telerobotic system was already discussed earlier. That looks very tough.

We have a program which we call the extended duration orbiter—an extension to 16 days for the lifetime of the orbiter, which would be very useful if we could do it. We had not intended to privatize that. We think that with some proper restrictions that we can get private financing of that, but we have to watch the safety of the astronauts that are flying, and I think we are close to a solution of dealing with that, but that is still tough too. Anything that is done in space is difficult. Then we have a proposed privatization of what we call the docking system. This is a system for the shuttle to dock with the space station, and again we are in difficulty there. We have not got a solution. So some of the programs look possible, Senator Rockefeller. Others look tough, and we are still working on them.

Senator **Rockefeller**. Mr. Chairman, I will just conclude with the comment that I really do respect all of you gentlemen for the work that you have done.

Dr. Fletcher, when you went through your confirmation hearing here earlier, I pointed out that you had been in this before. You did not have to return; it was the last thing in the world you needed to do, and yet you came back and your life has been filled with frustrations and delays since that time.

And each of you gentlemen and the thousands that work for you in NASA are to be commended. The advanced materials, the cure for cancer, the cure for diabetes—so much of the health of the world and the well-being of the world depends upon our NASA program and other countries' comparable programs succeeding. That means getting and keeping our best people, and you are a good one, so I am grateful that you have stayed.

Thank you, Mr. Chairman.

Senator **Gore**. Senator Lott.

Senator **Lott**. Thank you, Mr. Chairman. Let me get back to some of the specifics that we are trying to deal with in the hearing on your budget.

As you well know, when we have the static firing when we test the main engines, there are certain things you have got to have. One of them is a reliable and adequate supply of high pressure water, and so you had a project entitled "Modification of High Pressure Industrial Water System" that is needed if we are going to have the 15 or so static firings per month. Is that project included in this budget? Was it recommended, or is it in the figures that we were talking about that had been approved by OMB?

Dr. **Fletcher**. Senator Lott, I believe there is $2 million in for that project.

Senator **Lott**. Is that estimated to be the total cost that would be necessary to get that additional high pressure water supply?

Dr. **Fletcher**. Approximately so, Senator Lott.

Senator **Lott**. And there is a similar project, replacement of high pressure gas storage vessels. Is that included in this funding also?

Dr. **Fletcher**. Yes. I believe $3 million is in for that program.

Senator **Lott**. Let me go back to this assumption of third party financing. My attitude is that that is the same thing we should strive for, look for, and try to achieve, because it gives us the ability to get a lot more done with less direct federal dollars.

It may not always work, and if it does not work, if it is something that we really want to go forward with, we will have to find another way to come up with the dollars. Give me your overall reaction to the private, third-party financing. Is it working? Is it working a little, or not at all, or very well? In particular, how will it affect the ASRM that we talked about earlier?

Dr. **Fletcher**. Actually, Senator Lott, we have been involved in private financing for a long time. We started way back in my first tour at NASA, and we have learned from some of the failures, and we have also had some successes.

In my second tour we have done a number of things that seem to make sense, and they are on track. There is a program called

Spacehab which is a program to enlarge the area in the middeck region of the shuttle, which people want to build themselves and then charge customers for its use, and that looks like it is on track. We do not put any government money up for that.

There is another program which has not quite matured yet, but we advertised. We put a little notice in the Commerce Business Daily for the use of the external tanks. The external tanks are the centerpiece of the shuttle and we generally discard them and dump them in the Indian Ocean because we do not want them to come down on people.

Some private financiers indicated they wanted to deal with that and use those external tanks. At first they thought maybe they could use them in orbit, and there is fuel left over and there are some things you could do, but it is more expensive. They decided, so far, that the right thing for them to do is to make use of the 30 minute flying time and essentially microgravity as this external tank was diving into the Indian Ocean and go ahead and charge customers for its use. And that one seems to be on track, although it is not as far along as Spacehab.

And we have a number of what we call joint endeavor agreements. These are agreements to fill space. I do not want to say leftover space, but space normally used by the astronauts for storing their equipment and so forth, right behind the cockpit—the middeck, we call it—and there are a lot of experiments going in there that are privately financed. So some of them have worked out very reasonably well.

What we are now dealing with are some new spaceborne projects, and those are tough. And then some ground facilities, and three of those ground facilities, of course, were suggested by OMB, but the fourth one was our own, and we saw a way maybe to get the facility done earlier than we had anticipated, by going ahead and getting private financing, because we saw a shared use of the facility.

So we have made some mistakes, but that is—investors have to take risks, and so do we take risks. What we do not do is take risks where safety is concerned, and that is kind of a firm resolution on the part of NASA. If we can get around the safety problem, and if it seems like it has the likelihood of being financed we go ahead and press for it.

Some of the initiatives this year are—we haven't really made up our mind how we are going to do it, but there are only I think three of them that we are uncertain about.

You asked about the advanced solid rocket motor. That was an initiative last year. The Office of Management and Budget called our attention to the fact that the facility part of the advanced solid rocket motor could lend itself to public financing, because it might give the contractor a chance for us to locate it at a better place than we had picked, maybe saving the government money.

It does not look likely that the contractors will propose that alternate site, although we do not know. At my level we do not get involved in the source selection until the very end and I have not been briefed on it, but we have heard rumors that they are going to try to privately finance the Yellow Creek facility that we feel is optimal.

That was last year's problem, but we do need termination liability for that and I do not know which way it is going to go. We asked them to bid both ways, and if it does not make sense for the government we will not go for private financing.

If they can see ways of saving the government money, we will try to go in that direction and that is why we need the termination liability, because they are not going to do that without some sort of a guarantee from the government.

Senator LOTT. Thank you, Dr. Fletcher. Thank you, Mr. Chairman.

Senator GORE. What would be the incentive for a private company to finance the solid rocket motor facility on their own without government money?

Dr. FLETCHER. Mr. Chairman, I am not sure that if they center on the Yellow Creek site, if that is the site chosen it is hard for me to see where the savings would be. When we started out with this program we gave the contractor the option of picking his own site, and you can see some advantages of that. If it is located near one of his other facilities, transportation costs might have been less, and so forth.

But I think it is only fair to say that at NASA we are used to doing business the other way and we do not always see what the private investor sees, and so we ought to give him that option of showing how he can save the government money, and that is the track we are on. It may turn out that it will be government-owned/company-operated after all, but we have not made that decision yet.

Senator GORE. Well, if it had been your decision, you would have done that already. But you made that decision and then OMB ordered you to change your mind, and get private funding for it.

Now, Senator Lott said earlier it is impossible to find a better site. He was only partly joking on that, because in fact that is the case, and of course he and I have a particular interest in that site because it is in Mississippi and near the border of Tennessee.

But look at the circumstances: an abandoned nuclear site where the land has been prepared. It is an ideal location for a facility of this sort. You have a ready work force. You have the concrete poured in many cases, roads in many cases. It is just impossible to imagine finding a site that is anywhere nearly as well suited for this kind of venture.

It just mystifies me why all of the construction of facilities funds were deleted before the Source Selection Board was able to recommend a facilities financing plan. Does not this action severely prejudice an on-going source selection process?

Dr. FLETCHER. Actually, Mr. Chairman, the way it is structured we have asked the contractors to bid both ways, both private financing and government financing, and we really need to give them both a fair shake, both contractors that are bidding.

Senator GORE. You need to because OMB has told you to.

Dr. FLETCHER. Also——

Senator GORE. Force of logic does not dictate that.

Dr. FLETCHER. I want to just dispute that a little bit. It is because of the way the contracts, or the RFP was written. We asked them to bid both ways, and in all fairness to the contractor we ought to properly evaluate what he thinks is optimum for the government.

If we started over again we probably would do it differently, and as you know we had a site selection team and they evaluated all possible sites, and their conclusion was that the Yellow Creek indeed, as you point out, was optimum from the government's point of view.

Senator GORE. And you agree with that?

Dr. FLETCHER. I agree with their assessment, yes, Mr. Chairman. Having said that though, even though NASA is very smart and I am very proud of everything that they do, we are not always right. I hate to say that. It is always possible—and we think unlikely, but it is still possible—that the contractor will come up with a better idea than we came up with, and we have to give him that choice now that we have started down that track.

Senator GORE. Now that OMB has forced you to go down that track do the proposed reductions to the space flight budget ordered by OMB in any way compromise the safety or reliability of the space shuttle?

Dr. FLETCHER. I am going to ask Admiral Truly to comment on that, but while he is coming up let me say that we have a very tight margin. We call it allowance for program adjustment, because there is a lot of unforeseen things that we have to finance when we get to it, and it is a very tight program in Fiscal 1990.

I think we may be in trouble because of that small margin, in which case we are going to have to reprogram somewhere along the line. I will have to come back to you and ask for some sort of reprogamming action, but right now we think there is a fair chance that we can make it. At least that was my impression when we put the budget together, but I think Admiral Truly better answer that.

Admiral TRULY. I certainly think that the shuttle program today has never been tighter from a fiscal point of view, and if there is risk it is fiscal risk, but it is not safety risk. We have been, frankly, as have other parts of NASA, squeezed to see where there are parts of the program that we could do without.

But one place in the program that we have insisted on and refused to do without is the underpinnings of the program that we have put in since the *Challenger* accident—the ground testing, the engine testing, that sort of thing; and it would be my recommendation to reduce the flight rate rather than take cuts in the underpinnings at the flight rate we are trying to fly.

But as I said earlier, I believe with the infrastructure that is funded and the flight rates that are planned, even though it is a challenge, it certainly is one where we can supply the same risk assessment in the future as we have on these first two flights. If there is a risk in the program, therefore, it is a program management and fiscal risk, and it is very tight. But it is not a safety risk.

Senator GORE. In essence, what you are saying is that you are not going to allow it to affect safety or reliability. If you ever get to the point where you feel that commitment is under pressure, this subcommittee wants to hear about it instantly and without any delay whatsoever. We want to work with you closely to make sure you are able to keep that commitment.

Admiral TRULY. Thank you, sir.

Senator GORE. OMB forced you to cut one of the shuttle flights in 1990. Did you do that in order to avoid cutting into the safety and engineering money. Is that essentially correct?

Admiral TRULY. Well, if I might, we were to the point in the debate in the fiscal year 1990 funding, frankly, it was my recommendation to Dr. Fletcher that we remove that flight because I felt for the very reason that I just said——

Senator GORE. You would compromise safety otherwise?

Admiral TRULY. I was unwilling to compromise safety for the number of flights we had and with the budget pressures that Dr. Fletcher was facing, and with me trying to help him. It was my recommendation, I would rather take a flight out of that fiscal year than take a chance on the underpinnings of the program.

Senator GORE. I appreciate that response.

Now, Dr. Fletcher, let me just come back to your candid, realistic view of the implications of this budget. You said earlier you are leaving, you are a team player, but the team is the United States of America, and we are trying to understand the real implications of this budget.

An increase is requested, but the increase has been largely necessitated by the schedule of projects that were committed to long ago. Originally, the space station was in the hundreds of millions category. After it reached a certain stage, everybody realized it was going to take time to build it, so, instead of $400 million, it is $2.1 billion.

The space shuttle tragedy required expenditures that were unanticipated, and so the budget levels of a few years ago had to increase in the natural course of the ongoing space program.

Now, here we are with you coming to the subcommittee, having cut your programs as much as you possibly could, and then you went to OMB and OMB took another billion dollars out of your budget.

Now, let us say you do not get that billion dollars back. What does this budget do to the space program? Does it leave you feeling good about it? Are you comfortable that America's space program is on track or are we headed for real trouble at this level of funding?

Dr. FLETCHER. Mr. Chairman, it is kind of in between. If we do not get the private initiatives that we were speaking of, then there is well over $200 million worth—I do not know whether that counts in the ASRM or not—that would be a serious problem and could have really bad consequences.

If for some reason or other we were cut beyond the increase that we are asking for, that could result in a disastrous consequence also.

The budget that we have if fully funded is short of what we need. We do not have a vigorous program with that budget level as you properly pointed out earlier. We had to slip programs which are necessary. We had to eliminate programs which were very good. And I am just afraid that some of them may be put back at the expense of other parts of the program, and we cannot have that.

If any of those things happen, we are in trouble. And I would say we are on the verge of being in trouble now, but we are not there until we see what the Congress does.

Senator GORE. All right, now, let us talk about space station for a minute.

To make these matters worse, the Congressional Budget Office released its budget reductions options paper just yesterday, and included in this report are two options relating to the space station and space science programs. I understand these options had been provided to be reviewed by you and your staff. Do you want to comment on the merit of each of these options briefly?

Dr. FLETCHER. I am not sure we have been presented with those options.

Senator GORE. Do you know what I am talking about? This just came out yesterday.

Dr. FLETCHER. Mr. Chairman, I think you have the better of us on that one. We are not on top of that.

Senator GORE. Well, we will provide it to you then and let you respond for the record. You will not be happy with it. We are not. But the basic message of the CBO proposals is that if the projected funds are not available, and to date they have not been, NASA will have to go about prioritizing its activities in a very different way.

[The following information was subsequently received for the record:]

Space Science and Applications
Response to CBO Report on Reducing the Deficit

Starting new major space science initiatives on a regular basis is an absolutely essential part of building and maintaining U.S. leadership in space. Our current plans provide for planetary and earth science research and development efforts only through 1994. Since a major space science new start requires four to six years to develop, build and make ready for launch, delays to new starts today will have profound effects on the U.S. space science effort at the end of this century. Concluding that we cannot afford to begin new initiatives such as CRAF-Cassini, AXAF, and Eos is tantamount to saying that the resources and efforts that this nation is prepared to put into space science and applications are going to, not remain static, but actually decline.

CRAF-Cassini

o NASA has not initiated a new outer planet/deep space mission since Voyager was launched in 1978

o Even with a new start in FY 1990, CRAF will not begin to return data until the year 2000

o Launch opportunities for both CRAF and Cassini are perishable. The celestial mechanics of the solar system determine limited launch windows. Due to these structured planetary launch opportunities, these missions must start now or be delayed until the next century.

o Current international commitments to the mission, i.e. ESA contribution/participation in Cassini, are a 1990 commitment only; failure to achieve new start in 1990 results in lost opportunity.

AXAF

o Delays to AXAF development would irreparably hinder the synergism to be provided by operating the Great Observatories (HST, GRO, AXAF, and eventually SIRTF) together

o Timely development and launch of AXAF and SIRTF is imperative if their operational life is to significantly overlap with those of HST and GRO

o AXAF is the centerpiece of an international x-ray astronomy research program whose immediate results and use will help maintain the U.S. position of world leadership in x-ray astronomy.

Eos

o Delays in development will result in a delay in understanding the global changes already at work in the Earth's environment

o Most of the future data required to understand the complex functioning of our own personal life support system here on Earth is to be generated from missions developed and launched in the next few years

o Development of adequate environmental scientific expertise usually requires at least ten years of sustained research, delays in which could degrade the technical basis for virtually all U.S. policies relating to the environment

Aeronautics
Response to the CBO Report on Reducing the Deficit

The CBO Report contends that it would be beneficial to the National Aero-Space Plane (NASP) program to limit funding to zero real growth each year FY 1990 through FY 1994. The CBO conclusion is based on the premise that reduced funding would allow more time to resolve technical issues, such as lack of adequate ground facilities and mission identification.

Currently, the program is making excellent technical progress. To reduce funding in 1990 and slow down technology validation activities during this peak period could seriously jeopardize the program as it enters the final critical year of the technology development phase. Successful completion of this phase is necessary in preparing for the decision, in the fall of 1990, to build and flight test the X-30 research vehicle. 1990 will be a year of intensive testing of engine components, full-scale engines, and airframe structural components. Contrary to the CBO observation, all ground facilities needed for testing are available. Level funding in the 1991 to 1994 period is not consistent with funding profile required to design and build a flight research vehicle. No additional time is necessary to "develop basic missions" because the mission for the program from the beginning was to develop technology for a single-stage-to-orbit space transportation system, with the potential for flexible and rapid access to orbit. Operational applications for NASP-derived vehicles have been studied and it is clear that such vehicles will also have utility.

Slowing funding to the NASP program in 1990 could seriously impact the technology development phase which is needed to assess the potential of airbreathing engines for speeds above Mach 8, the current limit of ground facilities. This will be an intensive period of fabrication and testing of airframe and engine components including a large scale engine module. The contractors, with support from government teams, are reaching closure in the critical technology risk areas. Ground facilities for testing the engine components, full scale engines, and airframe structural components are available and scheduled. Two new engine test facilities that operate to Mach 8 were developed by the NASP program for this critical testing. NASA also has engine test facilities at both Langley Research Center in Virginia and Lewis Research Center in Ohio.

It is essential to hold the funding at the requested level to successfully complete this technology development phase and prepare for the X-30 decision. The program is making excellent technical progress in the areas of airbreathing propulsion, computational fluid dynamics and materials and structures. With a slow down in funding, engine testing would be curtailed and important tasks in the critical areas would have to be cancelled. The government, industry, and university national team of about 5,000 is actively pursuing the goals of the program. The industry portion includes the five prime contractors: General Dynamics, McDonnell Douglas, Pratt and Whitney, Rocketdyne, and Rockwell. Overall the program involves 200 contractors in 40 states. The prime contractors have invested almost dollar for dollar with the government and have built test facilities with their own resources. To slow funding as proposed would have grave effect upon the momentum of the national team and seriously erode the vital industry contribution.

Zero real growth in funding is not consistent with a funding profile for designing and building a flight research vehicle if the decision is made to do so. Typical funding profiles for hardware programs peak about two years before the roll-out of the first flight vehicle. The plan for the X-30 vehicle development projects such a funding profile. Limiting funding FY 1991 through FY 1994 to zero growth would delay fabrication of a potential flight research vehicle and greatly add to its cost.

The NASP management team is also reviewing potential applications for NASP derived vehicles. In addition to the exciting single-stage-to-orbit, the team is looking at a number of purely DOD applications.

If the X-30 decision were positive, in October 1990, the first experimental vehicle would be scheduled to begin flight testing in January 1995, or 50 months from go ahead. Consequently, the CBO view that the program "appears overly optimistic by historical standards" is incorrect because it is based on an estimate of 40 months.

It is imperative to maintain the planned funding pace of the program, the momentum and progress of the national team, and the U.S. world leadership in hypersonics vehicle technology. With a slow down in funding from 1990 to 1994, the first flight would clearly be delayed, the overall program cost would increase, and operational aerospace vehicles would be delayed.

Cancelling or delaying the Space Station Freedom program would be a serious setback for the U.S. space program. Further, it would jeopardize America's position as a world leader in civil space activities. We must follow through on our decision and commitment to build Freedom Station. It will allow us to perform scientific research on a scale never before possible in space, and to develop technologies for 21st century leadership in space and on Earth. We can use it to support the long-term goal human exploration of the solar system. And we will explore the unique opportunities the space environment holds for U.S. industry.

President Bush understands how important the space station is to the nation. When he presented his FY 1990 budget request to the Congress, he reaffirmed his commitment to a vigorous space program, and to the development of a permanently manned space station. He proposed to spend the remaining $515 million of FY 1989 space station funding and endorsed a $2.05 billion budget request for the space station program, stating "we must have a manned space station."

The nation has already made a major commitment to this program, and our progress to date has been significant. The configuration is firm. The right development organization has been established. Our contractor team is in place. The program requirements have been identified, and design activities are underway. Through the advanced development program, we have already developed some important space station hardware. In short, we have a strong program that is making real progress.

Moreover, as the CBO report acknowledges, the international dimension of this program is very strong. Our international partners have made strong national commitments to the program, and they rightfully expect the same degree of commitment from us.

It is a mistake to look at the space station program with a short-term focus and overlook the long-term payback. Space Station Freedom is a vital investment in America's future. It is a crucial investment for our leadership in space.

Senator **Gore**. Here are the two options: One, cancel the NASA international space station program. Cancelling the current space station program without initiating an alternative could save us as much as $5.1 billion in budget authority in the 1990–1994 period. There are a lot more supporting details, but that is basically what they present here.

And, secondly, postpone major new spacecraft development projects in a major NASA space science and applications program area. And they talk about postponing major new spacecraft starts would not prevent scientific work from continuing.

They list physics and astronomy, planetary exploration, the earth science and applications program and many others. We will provide this for you and give you a chance to look at it and review it and then respond for the record if you would be willing to.

Now, on the space station specifically, the proposed 1990 budget request contains a three-year space station budget request of $8.5 billion and proposes a cap of $13 billion in fiscal year 1984 dollars. Based on this three year request of $8.5 billion, would a permanently manned space station be deployed by 1996?

Dr. **Fletcher**. Mr. Chairman, with that funding the permanent space station would begin to be deployed in early 1995, but it would be fully manned by 1996.

Senator **Gore**. If the request is reduced, would it have an immediate effect on the proposed deployment schedule?

Dr. **Fletcher**. Yes, of course, if funding isn't available, we would have to slip the schedule or cancel it, depending on the size of the cut.

Senator **Gore**. Incidentally, we, of course, had a space station significantly larger than the one we are now proposing. It could have been kept in orbit. It could have been expanded in orbit and used today. I said larger. It was smaller than the full facility that's planned, but it could have been expanded.

We allowed that to burn up when it could have been kept in space for a cost of about $100 million, correct?

Dr. **Fletcher**. That was a long time ago, Mr. Chairman. It was on my first watch. I think you are talking about the Skylab program.

The Skylab program was put together with leftover parts from the Saturn V launch vehicle which got us to the moon, and the first attempt to use it was to use one of the upper stages as what we call a wet lab; that is, just use the stage and put some experiments.

From the scientific community's point of view, that did not make sense, so we upgraded it to what became finally the Skylab, which was an excellent program for the time that it was up and used, which was a little over a year. We really got some outstanding science programs, and it gave the whole world the incentive to do more of that kind of thing.

Microgravity became a science about that time. We, on my watch, and Mr. Myers was there at the same time, looked at a lot of possibilities for maintaining that in orbit, and I do not think we saw any way of doing it for $100 million or less, but perhaps after my watch was over, there was a plan for doing that.

Senator GORE. Maybe you could expand that response for the record.

[The following information was subsequently received for the record:]

Skylab and Space Station Freedom

Skylab was, in many respects, a precursor to modern "space station" concepts. It was thought that the use of a Saturn V launch vehicle stage as a laboratory would pave the way for a larger, more versatile space station that would more adequately meet our space science and exploration needs. Skylab provided very useful information in several areas, including solar observations, microgravity processing, Earth observations, and medical life sciences. Skylab's capabilities were, however, limited, particularly with respect to power, volume, and the potential for evolution. As you see from the comparison below, Space Station Freedom will be far more capable.

	Space Station Freedom	Skylab
Total pressurized volume (cubic feet)	32,140	14,513
Total mass without outfitting (pounds)	485,000	159,200
Peak power output (kW)	200	21.6
Average bus power (kW)	75	5.7
Crew	8 permanent	3 temporary
Unused attachment ports	10	0
Environmental control	Recycles air and water	No recycling
Available crew time (man-hours/year)	30,040	5,364
On-board propulsion	Thrusters	None

Senator GORE. Let me move on. Is the proposed $13 billion cap on the current space station program runout excluding prior and transition definition costs?

Dr. FLETCHER. That is correct, Mr. Chairman. That is our cap if the program is fully funded.

Senator GORE. The flight telerobotic servicers.

Dr. FLETCHER. Excluded.

Senator GORE. The orbital debris radar and space station operations?

Dr. FLETCHER. That is excluded, too.

Senator GORE. Does OMB agree with this definition?

Mr. CAMPBELL. Yes, it was jointly worked, sir.

Senator Gore. Does this cap assume that all space station facilities will be privately financed?

Mr. Campbell. No, sir. The cap remains.

Senator Gore. Now, why is the space station program cut in fiscal year 1990 below the fiscal year 1989 runout for fiscal year 1990 and the level authorized in the fiscal year 1989 NASA Authorization Bill?

Mr. Campbell. My speculation, Senator Gore, is that because of the constraint in the fiscal year 1989 funding where $515 million was removed from availability until the 15th of May, the OMB adjusted the 1990 value to correspond with what they calculated would be a reasonable buildup under those constraints.

Senator Gore. All right. Now, let me move to space science and applications.

In an effort to maintain a balance between the manned space initiatives and the space science program, a concerted effort has been made in recent years to maintain the space science program at 20 percent of the combined NASA space science and applications and spaceflight budgets. In the fiscal year 1990 budget request we fall below that level. There is only 18 percent for space science and applications.

Why was it allowed to decline to 18 percent?

Dr. Fletcher. Actually, Mr. Chairman, the budget as it came out of Congress over the last several years have been consistently above 20 percent. The appropriation, for example, in 1987 was 23.7 percent and in fiscal 1988 was 22.2 percent. Fiscal 1989 was 21 percent. So, to some extent, the average as it comes out of Congress has been considerably above that 20 percent figure going in.

Sometimes in the early part of that period we had a larger percentage of the total and it stayed close to the 20 percent. The President's budget for fiscal 1987, fiscal 1988——

Senator Gore. Why is it below in 1990?

Dr. Fletcher. Simply that we had an adequate space science program, and we got squeezed pretty tightly that $1 billion. Somebody had to give up something.

Senator Gore. So, OMB forced you to do it.

If the advanced communications technology satellite, the Gravity Probe B and the ozone mapping instruments were included, would it have been 20 percent?

Dr. Fletcher. It would be almost 20 percent.

Senator Gore. Does NASA consider this target to be reasonable and will the downward trend in space science funding be corrected in the 1991 through 1994 budgets.

Dr. Fletcher. Mr. Chairman, we do not notice a downward trend.

Senator Gore. Well, since 1988 here is the graph. There is a little of an erratic pattern, but you can see that for the last three years there has, in fact, been a downward trend, 1988, 1989, 1990, rather consistent.

Now, there was—and you can take it back to 1986, although 1987 was an aberration with a very sharp drop. But for the last three years, there has been a downward trend and overall for the last five years there has been a downward trend.

Dr. **Fletcher**. I think we have tried to keep it about to the 20 percent that we have committed to, and actually we have ended up over the 20 percent figure. We really cannot, Mr. Chairman, year by year hold to exactly 20 percent. I think, though, that is our target.

Senator **Gore**. It is just a benchmark to measure what you are doing, and the trend is in the wrong direction.

Dr. **Fletcher**. The trend is downward, but it is still well above 20 percent. Except this year's presidential budget. But Congress is not through with that budget yet.

I would just give you one example, and that is the ACTS. Congress keeps putting that back in, and if it does and puts some of the other things back in, then it very well may come to 20 percent again.

Senator **Gore**. Does the NASA/OMB 5 year runout assume new start status for any of the space science missions and research base enhancements that are outlined in the new office of space science and applications strategic plan?

Dr. **Fletcher**. No, it does not. It is simply a runout of this year's program.

Senator **Gore**. All right. Moving to another subject, over the course of the last few years NASA has initiated several new space technology initiatives that were geared to making a decision in 1992 as to the next major NASA initiative. Four of the most frequently discussed options were outlined in the NASA report "Beyond Earth's Boundaries."

In light of the fiscal year 1989 reductions to the Pathfinder program and the substantially reduced fiscal year 1990 request for this program, is 1992 still the time frame for a major policy decision on a future NASA mission?

Dr. **Fletcher**. Mr. Chairman, if you took our program literally, you would have to say 1992 would have to slip. This is a technology program and if you want to have that technology well under your belt, you really ought to either fund it more in the out years or you ought to fully fund it this year.

We had hoped to fund it this year somewhere between $100 and $200—I have forgotten the exact figure, but we can supply that. We have not put that much in the budget and, therefore, it might postpone a presidential decision.

Having said that, though, it is always possible if the country wants to, we can make the decision to go forward and take the risk that technology will evolve as part of the new initiative.

Senator **Gore**. All right, I am going to ask you to respond for the record on the levels of funding that would be required if the committee supported the decision in 1992, the level that would be required for the civilian space technology initiative, the Pathfinder program, the in-space flight technology program, and the core NASA technology program.

Dr. **Fletcher**. We can do that, Mr. Chairman.

[The following information was subsequently received for the record:]

The Space R&T program consists of three ongoing programs, the R&T Base, the Civil Space Technology Initiative, and the Pathfinder program, and one FY 1990 new initiative, the In-Space Technology Experiments program. The overall Space R&T program represents an appropriate balance of focused and fundamental research, of ground and flight research and of applied and basic research. All elements of the program contribute to the revitalization of the Nation's civil space capabilities and will enable potential future civil space missions.

The Pathfinder program is specifically designed to provide the key technical and engineering data essential to a well-informed decision on any potential future solar system exploration mission.

At the current proposed budget levels, Pathfinder could support an informed decision on a future solar system exploration mission sometime during the 1990s. However, the key thing to remember is that the availability of information and the level of technology readiness must be the guiding lights for decisions on specific missions and timetables. Artificial or arbitrary decision dates, not supported by technology readiness, invite risk, cost growth and delays.

The core Research and Technology Base program is the ongoing fundamental research foundation upon which future civil space capabilities are built. This program includes ongoing, long-term basic research in areas such as advanced materials, information systems, and advanced propulsion and power concepts.

The Civil Space Technology Initiative is an ongoing focused program designed to provide technology in support of transportation to, operations in and science activities in near Earth orbit. This program was initiated in FY 1988 to fill widely recognized gaps in the research and technology base and was the first step in an overall revitalization of the Nation's civil space capabilities.

The In-Space Technology Experiments program is proposed as an FY 1990 initiative that will develop and validate key technologies required to operate in space which cannot be tested on the ground. It is designed to extend the Nation's space research and technology efforts beyond the limitations of ground-based laboratories and utilize more fully the current space infrastructure, such as the Space Shuttle and ELVs, as well as lay the groundwork for Space Station Freedom utilization in the 1990s.

Dr. **Fletcher**. Mr. Chairman, it is hard to know with all of the other considerations that a new president has where space comes, but I happen to know President Bush personally, and he's always been an enthusiastic supporter of the space station, and I think so indicated in his campaign, and I would be surprised if he did not continue to support a vigorous space program.

Senator **Gore**. We all would be, Dr. Fletcher. We are waiting to see the follow-through on that commitment. When the program was first announced, instead of being treated like the Apollo program, immediately the director of the Office of Management and Budget launched an inquiry as to whether it was necessary. We used to do things differently. We will see whether there is a difference in this Administration. I hope there is. And I hope that this Administration is committed to keeping the space station on schedule and providing the necessary R&D, spaceflight, construction of facilities and personnel resources to implement the program.

In that regard, what cuts or deletions, if any, will the NASA budget from President Bush make compared to the budget from President Reagan, and when will the committee receive these changes?

Dr. **Fletcher**. Mr. Chairman, I do not anticipate any changes from President Reagan's budget in the Bush budget. I have no knowledge of what he is going to present, but as soon as the information is available, we will come back to you and indicate any changes which might have occurred.

Senator **Gore**. Good. Well, I certainly appreciate that, and we have other questions for the record.

We will be pursuing these and other matters very closely and diligently in the weeks and months ahead. I look forward to working with you and your team at NASA, Dr. Fletcher, and we deeply appreciate your getting the subcommittee off to a good start. We will be in constant and close communication with you. Thank you very much.

[Whereupon, at 11:55 a.m., the subcommittee adjourned, subject to the call of the Chair.]

[The following information was subsequently received for the record:]

Responses to Written Questions Submitted by Chrm. Gore.

Five-Year Projections

Question 1: Dr. Fletcher, by March 8, 1989, this Committee is expected to submit to the Senate Budget Committee its best estimate of the NASA budget requirements for FY 1990-FY 1994. As you can well imagine, the Senate Budget Committee would prefer that we find "budget savings" -- not additional requirements. However, it is quite clear to me that implementation of the proposed NASA program will require additional resources in the FY 1991-FY 1994 time frame.

a. Dr. Fletcher, would you please give the Subcommittee your best estimate of the additional NASA requirements that are not included in the five-year budget runout supplied to the Committee with the budget submission?

For example, what new starts and initiatives are currently being assessed by NASA as part of the FY 1991 budget review? And what is their estimated dollar value?

Answer 1: The current five year runout for NASA as reflected in the President's budget does not include any new starts or provision for adjustments after FY 1990. Those are normally approved one year at a time during the budget formulation process.

The FY 1991 budget review process has not begun yet but it is possible that a total additional requirement to the runout could be in the range of $1-2 billion in the out years. The funding would include new starts and amounts to cover adjustments and augmentations that experience has shown are needed each year when the detailed budget is prepared. Based on preliminary plans for FY 1991, candidate new starts could include the following which are not ranked in priority order:

	Estimate FY 1991 Funding (million of dollars)
Aeronautical R&T Initiatives	0-50
Earth Observing Systems	0-120
Earth Probes	0-10
Life Sciences Initiatives	0-50
Shuttle C	0-150
Space R&T Initiatives	0-50

The above is very preliminary and a final agency decision on which new starts would be recommended will depend on the definition of the project and the overall health of the on-going NASA programs.

Multi-year Budgets

Question 2: Dr. Fletcher, as you know, there was a lot of discussion last year about formulating a multiyear authorization bill. The basic argument for such an initiative was that it would facilitate planning and provide predictability. This year, as a matter of fact, NASA was required to submit a multi-year budget request for FY 1990 and FY 1991, as well as budget projections for FY 1992.

a. Dr. Fletcher, in your opinion, what benefits are there with multi-year authorization bills? And if the Congress decided to pursue such an initiative, would NASA and OMB provide support and outyear estimates reflecting NASA's real budget requirements including new starts, new initiatives, additional personnel and facilities requirements?

b. If the Appropriations Committee did not provide multi-year funding, would any of the benefits attributed to a multi-year authorization bill be lost?

Answer 2a: The benefits from a multi-year budget might include better management of programs and resources due to an increase in stability gained from having a known funding level for several years at a time. However, NASA programs by their nature involve uncertainty and require that flexibility in funding be maintained to accommodate unforeseen technical or schedule problems. A multi-year authorization request would provide stability in planning the total agency level of resources available, however, there would still need to be a special effort made to provide mechanism for adjustment within the overall totals each year. Furthermore, if it is not accompanied by a multi-year appropriation, the benefits would be lost since funding would still be on a year to year basis.

b. We believe the Administration is supportive of a multi-year budget. The President's FY 1989 and 1990 budgets proposed a three year appropriation for Space Station. The FY 1990 President's budget also contains a number of proposals to reform the Federal budget process, including biennial budgeting.

Question 3: As you are probably well aware, there is considerable interest in this Committee and in the Congress for the Mission to Planet Earth and to NASA's key contribution to this mission -- the Earth Observing System.

As proposed FY 1991 new start, NASA was not permitted to include the cost of the EOS program in its FY 1991 budget request.

a. Dr. Fletcher, based on the information you have gathered to date, what is the estimated cost of the EOS program in FY 1991? Is it true that the estimated cost of the instruments for EOS I and II is currently $3 billion?

b. What is your best estimate of the level of funding required for the EOS initiative in FY 1992-FY 1995?

c. Does NASA consider the Earth Probes Program to be an element of the Mission to Planet Earth, or is it a precursor necessary to verify the technology proposed for key instruments?

What are the key payloads in the Earth Probes program, and what is the total estimated cost of this program?

d. Based on the various studies that have been done to date, what are the critical elements of the Mission to Planet Earth and which agency has the lead for each of these components? What is the proposed timing for each of these elements of the Mission to Planet Earth program?

e. Am I correct to assume that the Bush Administration had endorsed the Mission to Planet Earth and that the White House Council on Earth Sciences Implementation Plan will lay out the framework for this program?

Answer 3a: In any budget discussion of the Earth Observing System EOS), it must be noted that since certain key reviews and decisions have not yet been accomplished, all cost estimates are preliminary and likely to change depending on Agency and Administration budget decisions. The information provided here is given on the basis of our current best estimate as to the configuration and instrument complement of the EOS program, which is still in definition (Phase B) stage. Now that the Announcement of Opportunity selections have been made, non-advocate cost reviews scheduled for this summer will better determine the requirements, capabilities, and resource constraints of the system.

b. The annual funding requirements are currently under review and will be determined at the non-advocate cost reviews to be held this summer. The final estimates will depend on the content, schedule, and pace of the program.

c. The proposed Earth Probes program is not a technology precursor to the Earth Observing System, although it is envisioned as a scientific complement to the EOS observations, filling in the gaps that can only be covered by smaller, more specifically targeted free-flyers. Technology verification is currently being accomplished through precursor instruments being flown on research aircraft and the Shuttle. The potential key payloads in the Earth Probes program, as originally conceived, include:

- o Total Ozone Mapping Spectrometer (TOMS)
- o Sea-Wide Field Sensor (Sea-WiFS)
- o Geopotential Research Experiment Mission (GREM)
- o Tropical Rain Measurement Mission (TRMM)
- o Joint Magnetic Mission (JMM)
- o Mesosphere Explorer (ME)

The studies for these projects are currently in the early definition phase. The program would be managed similarly to the Physics and Astronomy Explorer Program, in which spacecraft development is phased according to funding availability within a level-of-effort budget. The Earth Program is planned to build to a $40-$60 million level-of-effort per year.

c. The Mission to Planet Earth program described in the "Sally Ride Report" is a very preliminary concept study of a possible future mission. With the exception of some preliminary study funds for the Earth Observing System EOS) and Earth Probes, EOS and Earth Probes are potentials new starts in the future as described in the

Office of Space Science and Applications Strategic Plan. Even if NASA were to have funds, we are not technically ready at this time to initiate EOS, nor it is clear that we would actually implement Mission to Planet Earth in its current conceptual framework. We have a lot of planning and studies yet to do before we could or should commit to such an ambitious and costly mission.

Our current vision of Mission to Planet Earth is a research program that would consist of both space and ground elements. The space elements would include a series of Earth observing platforms, both small and large, in various orbits about the Earth, and instruments attached to the Space Station Freedom. The purpose of the space elements would be to gather long-term global data sets on the surface and the atmosphere of the planet. The principal ground element is a data and information system to gather, process, and archive the data accumulated from the space elements. The information archived in the data and information system would be accessible by the entire would-wide scientific community. The information would consist of global maps of surface temperature, precipitation, soil moisture, cloudiness, radiation budget, and other such global data sets required to understand the state of the Earth and any trends for change.

d. There is been no decision on the Mission to Planet Earth program at this time.

Third Party Financing

Question 4: Dr. Fletcher, the FY 1990 NASA budget request includes a variety of initiatives for which third party financing is assumed, seven if I'm correct, estimated to avoid $208 million worth of budget authority in FY 1990 and $802 million in budget authority over several years.

a. Dr. Fletcher, were these third party financing proposals NASA initiatives or OMB initiatives

b. Correct me if I'm wrong, but aren't all seven of these projects exceptions to the OMB leasing policy spelled out in OMB Circular A-104? As long as you've been Administrator, have you ever been told to make "seven" exceptions to an OMB policy before?

Answer 4a: The proposal for third party financing of the seven initiatives included in the FY 1990 budget request evolved out of the budget process resulting in a joint decision between OMB and NASA.

b. The OMB Circular A-104 provides for exception to the policy in the case of unique facilities. It is NASA's view that private financing of these facilities fits within this exception, although we are prepared to push hard to private sector equity participation.

Justification -- Ideological or Analytical

Question 5: Dr. Fletcher, the staff of this Committee was recently briefed on three of the four facilities being proposed for private sector financing. During the briefing, they discovered that

NASA was instructed to assume third party financing in late November of last year because some contractor/investor interest had been manifested or because OMB thought these activities had potential shared use capabilities.

a. Dr. Fletcher, were these seven projects selected because a detailed analysis had been performed according to A-104 or because OMB had to reduce NASA's FY 1990 budget, and this was a good gimmick?

b. Isn't it true that NASA did not start to analyze the economies of three of these facilities until December 1988 and that this analysis wasn't completed until January 1989?

c. Isn't it also true that the analysis for the hardware portion of this initiative is still being compiled?

Answer 5a: The seven projects were identified as possible candidates for private financing because they were not yet under contract and in several cases, specific interest had been shown by the private sector in a private financing arrangement. These projects were thought to be good candidates for some kind of financing arrangement by the private sector.

b. Yes - the three facilities were submitted as part of the OMB budget request and the analysis was done after it was decided to pursue private sector investment. The analysis was started in November 1988 and has been updated several times as financial conditions and assumptions have changed -- the most recent being on February 8, 1989.

c. The analysis for the hardware elements is still being done.

Question 6: The 1990 NASA budget estimates frequently refer to the National Space Policy released in summary form in February 1988, as the basis for the commercialization initiatives.

How can the seven specific proposals in the budget be related to that policy.

Answer 6: The White House Press Release - FACT SHEET on Presidential Directive on National Space Policy issued in February 1988 contains the following statements:

"Overall goals of United States Space activities are: ... (3) to encourage continuing United States private-sector investment in space and related activities..."

"Government sectors shall encourage, to the maximum extent be, the development and use of United States private sector space capabilities without direct Federal subsidy."

These statements clearly reflect the intent of the National Space Policy which is to encourage private sector investment in space activities. The proposals contained in NASA's budget request are consistent with that intent.

Question 7: Under what conditions would it be cost effective for the Congress to allow NASA to go forward with the privatization proposals?

Answer 7: The lease or service contract arrangement can be less expensive to the government than direct procurement if the use and cost of the hardware infrastructure or facilities can be shared with other customers on a basis that would not interfere with NASA programs and NASA would not have marketed, or hired an agent to market, the available hardware infrastructure or facilities to the private sector if NASA had pursued a direct procurement. The lower payments permitted by sharing the hardware infrastructure or facilities must be sufficient to offset the highest cost of borrowing at the private, rather than the government, rate.

Question 8: Several weeks ago NASA briefed staff on an analysis of three of the four construction projects proposed for private financing.

Am I correct in understanding that privatization would cost the government an additional $15 million if NASA were to end up as the sole user of the facilities built?

Answer 8: NASA intends to vigorously explain private sector use of these facilities. These facilities were chosen as reasonable candidates for private sector development precisely because they had the possibility for shared use by both the government and private sector.

Second, analyses of the relative economic advantages of lease vs. purchase are sensitive to the economic assumptions that are used, thus, any advantage of one approach over another can only be estimated until firm proposals are in hand and evaluated. Our preliminary analyses indicate additional cost in the $15 million range associated with the government as role user.

Question 9: Is NASA and the Administration prepared to go forward with these projects if they cost the government money?

Answer 9: NASA has been charged with the responsibility to seek and encourage private sector involvement in the commercial development of space in both the Space Act and the Presidential Directive on National Space Policy. While we will look most favorably at those proposals which are economically advantageous to the Government, we must not exclude consideration of the long term economic benefits of space commercialization to the nation. Therefore, we must look at each project separately and evaluate the project's ability to foster viable space markets and reduce government outlays in the long term. It is through this individual evaluation process that we will determine those projects which merit further support.

Question 10: The Office of Management and Budget has issued general guidance to Executive Departments and Agencies discouraging the substitution of lease-purchases for outright purchases of federal assets. An October 1988 memorandum from Acting Director Joseph Wright to department and agency heads affirms that policy.

Now, I am aware that the same memo provides for exceptions as designated in the annual budget review process. I might also add Mr. Wright's memo explicitly rejects the idea that Congress could introduce such exceptions.

Nevertheless, if the seven NASA third party financing proposals are exceptions and could end up costing the government money, how were the particular exceptions justified in the discussions between OMB and NASA? What level of approval is required to insert an A-104 "special purpose facility" exception in the budget request?

Answer: NASA and OMB feel these projects are good candidates for private financing and in turn, encourage private sector participation in space. The approval of OMB is required for an A-104 exception "special purpose facility".

Question 11a: What is the focus of High Speed Commercial Transport program, and what is the current estimate of the potential market for these aircraft? What foreign countries are active in developing high speed transports for this market?

b. Would you please give the Committee an idea of the scientific value of the CRAF-Cassini mission and the degree of foreign participation? Is this mission a higher priority than the Earth Observing System that is a FY 1991 new start candidate, or the Advance X-Ray Astrophysics Facility that was approved in FY 1989?

c. If the Space Science and Applications Budget Request for FY 1990 were reduced, should these new initiatives be funded?

d. If the Aeronautics Budget Request for FY 1990 is reduced, should this new initiative be funded?

Answer 11a: Long-haul transpacific travel is currently the fastest growing market and is expected to quadruple by the turn of the century. Because of this rapid growth and the extremely long flight times with subsonic aircraft, there may be an increasing need for future high-speed aircraft to provide more effective service. Studies have indicated that, with sufficient technology development, these future high-speed aircraft could be economically competitive with long-haul subsonic aircraft. In this case, the projected traffic growth would provide a projected market for 650-750 aircraft by the year 2015. Currently, however, critical environmental concerns about atmospheric impact, airport noise, and sonic boom present powerful private sector disincentives. In addition, the economic of such new aircraft would have to be carefully considered by potential private users.

The NASA High-Speed Research program, to be initiated in FY 1990, will address the resolution of these barrier environmental issues and develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental issues will place the U.S. in a position to make informed decisions on high-speed aircraft technology development in the future. The program builds on NASA's extensive efforts in upper atmosphere research and previous experience in airport noise reduction technology and sonic boom reduction. The atmospheric research addressed in this program involves two elements: long-term atmospheric chemistry assessment and low emission combustor research. The primary focus is to develop advanced technology combustor designs with low enough nitrogen oxide emissions for environmental compatibility. The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression aimed at providing the technology for meeting FAR 36 Stage 3 noise levels, the same levels achieved by the quietest subsonic aircraft. The sonic boom reduction research addressed in this program includes aircraft configuration research aimed at reducing the sonic boom levels combined with human response evaluations to define the criteria for acceptability.

Several countries have efforts underway directed at future high-speed civil transport aircraft. The French company, Aerospatiale, has continued to develop the technology for an advanced SST ever since the Concorde program. Over the last ten years, they have concentrated on a series of Avion de Transport Supersonique Futur (ATSF) configurations. The ATSF would be a follow-on to the Concorde with a cruise speed between Mach 1.8 and 2.2, range of 6500 n.mi., carry 200 passengers, and meet 1990 noise requirements. At a lower level of effort, Aerospatiale is also considering a higher speed transport called Avion a Grande Vitesse (AGV). This aircraft would cruise between Mach 4 and 5, carry 150 to 200 passengers, have a range of 7500 n.mi. and use liquid methane fuel. The British have conducted research on a manned transatmospheric vehicle project called HOTOL (Horizontal Takeoff & Landing). British Aerospace and Rolls Royce have proposed potential future commercial passenger vehicle versions of HOTOL. In Germany, MBB is currently studying the Sanger Space Transportation System. This two-stage transatmospheric vehicle has a first stage that could be modified to provide a 230 to 250 passenger, Mach 4 to 5 transport aircraft. Japan has initiated concept definition and research for a Mach 2.5 to 5 commercial transport aircraft. The current Japanese program has been reported to be about $300 million, primarily for high-speed propulsion. The Japanese have also been very active in pursuing foreign partners for high-speed transport development and acquiring information on applicable U.S. research efforts. And, although the evidence is limited, the Soviet Union has developed large high-speed research facilities and has conducted fight research apparently aimed at liquid methane or hydrogen-fueled supersonic aircraft.

b. The Comet Rendezvous Asteroid Flyby (CRAF) and Cassini (Saturn Orbiter/Titan Probe) missions combine to form the first initiative in a new generation of spacecraft, the Mariner Mark II. This set of planetary missions is designed to explore the outer solar system and primitive bodies such as comets and asteroids, toward the ultimate goal of understanding the origins of life. The mission also seeks to answer whether the Earth and planets natural results of star formation, and if life itself is a natural result of solar system evolution.

The chemistry that gave rise to life in the past is no longer available for us to study. Therefore, only by studying material essentially unaltered by the sun's heat and radiation can we find clues to these important questions about the origin of life here on Earth. Outer solar system bodies provide an accurate archeological record of the formation of the sun and surrounding planets. Comets are particularly unique because they are believed to contain, intact, the original material from which the sun and planets were made. This primitive matter may be representative of the original collapsing nebula that formed our solar system. It is believed that since the early Earth did not contain sufficient water or perhaps even carbon to form life, these necessary elements were provided by comets colliding with the Earth.

In order to gather the necessary data, CRAF will fly by at least one asteroid, orbit a comet, and drive an instrumented penetrator into the comet's nucleus. Cassini will also fly by one or more asteroids, orbit the planet Saturn, and repeatedly fly near many of Saturn's moons, sending an instrumented probe into the atmosphere of Saturn's large moon Titan. These two missions are complementary because their subjects have a common origin in the outer solar system and provide the most easily accessible arenas in which to study the original materials from which the Solar System, and perhaps life, may have formed.

Both missions will use virtually identical Mariner Mark II spacecraft designed and built by NASA. Foreign participation includes the Titan probe developed by the European Space Agency (ESA), and the CRAF propulsion subsystem developed by the Federal Republic of Germany (FRG). Scientific instruments will be supplied by all the international partners. The ESA contribution of the Titan probe, however, is vulnerable; it has been indicated that they will move to develop alternative program initiatives if we are unable to make an FY 1990 commitment to proceed with Cassini.

CRAF-Cassini was presented as an FY 1990 combined new start for a specific reason. We are facing a decision on a perishable opportunity. In a few years the alignment of the planets that made the Voyager grand tour possible will change, and a trip of reasonable length to Saturn will no longer be viable since Jupiter will have moved too far away to enable the proper trajectory. To gain the necessary momentum to reach a comet, our current launch capability dictates that a spacecraft must swing by Venus. However, the launch opportunities where Venus and a comet are aligned within a reasonable distance from one another are absent in the late 1990s, requiring trip times of approximately nine years. If CRAF-Cassini is not started now, optimal planetary launch window will not open again until the turn of the century. With the approval of this FY 1990 start, we will create a planetary exploration program for the United States that is active, exciting, and respected well into the next century.

There are two keys to the sequence in which NASA has presented the new start initiatives of AXAF, CRAF-Cassini, and EOS First, the technological readiness of each mission was assessed in terms of work done to date and ability to go forward with stated schedules. Second, and equally important, was the sense of urgency surrounding the mission; the order was dictated by their development period and the years in which they were needed in terms of planetary launch windows or work in conjunction with other facilities. Within NASA, each of the missions has highest priority because each represents distinct and separate fields in space science; namely, Astrophysics, Solar System Exploration, and Earth Science and Applications, respectively. These missions are vital in maintaining traditional U.S. preeminence in these critical areas of space science; therefore, they are all given equal priority.

c. If the Space Science and Applications budget request for FY 1990 were reduced, whether these new initiatives should be funded depends in large part on the size of the reduction. The problem with a delay to the CRAF-Cassini initiative lies in its perishable launch opportunities. As has been stressed before, NASA feels that the CRAF-Cassini mission is absolutely essential in ensuring that the U.S. regain and maintain its world leadership role in solar system exploration. In the case of a small reduction, NASA feels strongly enough about the merit and contribution of the mission to proceed with it, in most part because the OSSA strategic plan requires the orderly progression of new starts in order to achieve the goal of world leadership in space science. Without the national commitment to initiate and continue programs once begun, we will never be able to achieve the benefits and goals of the strategy.

d. Possibly on a limited basis. Within difficult fiscal constraints, NASA is continuing to make the tough programmatic decisions to focus the aeronautics program in those emerging technologies that offer major improvements in performance. Today, the opportunities for technological advancement in aeronautics are as great or greater than any other time in history. At the same time, our competitors are increasing their investments in R&T and design studies to enhance their positions for a future aircraft development. Delaying the High-Speed Research initiative would provide our competitors with increased opportunities to improve their future position -- in an area which offers a major market opportunity and threat to our industry.

Personnel System Reform/Personnel Requirements

Question 12: Dr. Fletcher, a critical ingredient of the Nation's Space Program is the NASA civil service personnel. During FY 1989, passage of a personnel system reform measure, S.2530, that was strongly endorsed by NASA, DOD, OPM, OMB and several other agencies almost got enacted.

a. Dr. Fletcher, how high a priority is a personnel reform system modeled after the Navy's China Lake experiment? Would the Bush Administration endorse such a proposal in the 101st Congress?

b. Besides personnel reform, what other critical personnel issues face NASA and other Federal agencies that require technical/scientific/engineering skills?

c. What is the status of NASA's current effort to get the Appropriations Committees to approve a FY 1989 change in operating plan to augment the civil service workforce? How many additional slots does this involve, and where will these additional personnel be deployed?

d. Is it true that the Space Station Level I and Level II offices are currently staffed at approximately half the required manpower -- 238 people, compared to a requirement of 444?

Answer a: Personnel system reform is still a priority in NASA. While the agency was disappointed when the reform legislation was not enacted in the last Congress, NASA's interest in this area has not waned. In fact, in the absence of legislation, we have been working with the Office of Personnel Management (OPM) regarding the feasibility of implementing a new personnel system in several organizations of NASA, under OPM's legislative Demonstration Project authority. However, our preference is still to pursue legislation. After further design development work has been completed on the Demonstration it appears that we would have the knowledge to allow us to implement major personnel reform on a NASA-wide basis. The Bush Administration has not indicated its position on this issue.

b. The issues concerning our civil service personnel are interrelated. The facts of each issue influence our ability to resolve the others. The most difficult issues are:

1. The need to enhance the core scientific and engineering capability, and to strengthen program management, operations, and the institution.

2. The ability to attract and retain the best talent available.

3. The increasing potential for talent loss through retirement.

During the summer of FY 1988, NASA conducted an in-depth review of its manpower requirements. The results of the study indicated that based on Space Station program needs as well as Research and Technology base requirements, NASA would need a significant increase to its current workforce. In discussions with the OMB relative to the results of the manpower review, OMB agreed that NASA's FTE ceilings be increased in FY 1989 to 23,734 and to 24,007 FY 1990. Current budget levels will not allow NASA to meet OMB approved higher ceilings, thus this budget is predicated on NASA's ability to fund FTE levels of 23, 150 in FY 1989 and 23,846 in FY 1990 including the IG. NASA remains committed to achieving OMB approved ceilings for both FY 1989 and FY 1990. Every possible effort will be made to secure funding so that planned programmatic activities can be realized. Additional needs will be pursued in the coming budget cycle for future program needs.

We are finding it increasingly difficult to attract talented people at all levels, and all indications are that the supply and demand situation will only get worse. Current studies project that shortages in critical engineering disciplines and decreasing enrollments in engineering schools are expected to persist well into the 1990's. The National Science Foundation has estimated shortages in the range of 20 to 30 percent of the total demand for aeronautical engineers and computer specialists during this period.

The projected shortages of highly skilled talent, when coupled with the widely accepted fact that Government salaries and benefits are not competitive with the private sector does not bode well for NASA's future. Recent studies show that the salaries we can offer entry-level scientists and engineers are $6,000 to $10,000 behind the private sector. The recent debate on congressional salary increases brought before the public the noncompetitiveness of Government pay at senior levels.

Our technical managers and engineers are finding it increasingly attractive to retire early and enter second careers in industry, often at salaries 50 percent to 100 percent more than their highest possible government pay. Similarly, top-rank scientists are recruited to academia at salaries in the $100,000 to $120,000 range, plus consulting privileges. When the managers in the top tier leave, NASA does not have, and frequently cannot hire, comparable talent in its middle ranks to fill in.

The potential for wholesale losses through retirement is rapidly growing. At present, 70 percent of NASA's Senior Executives are eligible for retirement-nearly 25 percent voluntarily. Within the next 2 years this situation will worsen as the number of voluntary eligible Senior Executives and top managers rises to one-third of that same total population. And, in the next 5 years voluntary eligibles will increase to well over 50 percent.

Action to improve the Government's competitiveness in this regard must begin soon if we are to attract and keep the very best. The result of long delays will surely lead to low morale and a deterioration of NASA's ability to attract and retain a quality workforce.

c. The most current operating plan, dated January 4, 1989, reallocated $10 million within R&PM, from Operation of Installation to Personnel and Related Costs, to allow for an initial staffing augmentation of 200 additional FTE's. This is an interim action however, until FY 1989 transfer authority from R&D and/or SFCDC appropriations to the R&PM appropriations is obtained to cover the cost of additional workyears. The committee staffs have been thoroughly briefed on these requirements and NASA will continue to work with the committees to obtain transfer authority.

d. The Level I and Level II offices are now staffed with 240 full-time employees. They are currently authorized to staff to a ceiling of 275. Our agency FTE augmentation of 200 addressed in question 12c will provide the additional ceiling toward staffing these offices at the required level.

Question 13: Dr. Fletcher, the Subcommittee compliments you for getting OMB to approve this new line item and inclusion of $5 million in funding for the National Space Grant College and Fellowship Program in FY 1990.

a. Would you give us your current thinking on the Space Grant College and Fellowship Program, and do you still intend to select six designated institutions in FY 1989?

b. By what fiscal year will this program be fully funded at $15 million?

c. It is still your intention to expand the program in FY 1990 and to fund the fellowship and program grants portion of this program if we provide the appropriations?

d. In the current NASA budget run for FY 1991 and FY 1992 what augmentations are assumed for each of the programs in this new line item -- University Affairs, Minority University Research, and the National Space Grant College and Fellowship Program?

Answer 13a: In developing The National Space Grant College and Fellowship Program considerable planning and coordination was required between NASA the university community. The program is composed of three complementary elements: "Designated Space Grant College/Consortia", Space Grant Programs, and the Fellowship Programs. The National Space Grant College and Fellowship Program is currently under development and the designation phase will be implemented in FY 1989. Plans currently call for the program announcement to be made public and distributed to the university community in April 1989, with proposals due in June. It is our intent to select approximately 12 Space Grant Colleges/Consortia in FY 1989.

b. The agency plans to phase in the elements of the program and contingent upon the interest expressed by the university community, we would hope to reach an annual level of roughly $15 million by FY 1992. That funding level of course, will be dependent upon funding availability relative to the needs of other high-priority programs.

c. If the funding level requested in NASA's FY 1990 Budget Estimates is approved, it is our intent to fund fellowship at all the Space Grant Colleges/Consortia and to possibly provide initial funding for some Space Grant Programs. We feel it important to receive the advice and counsel of designated schools on the Space Grant Program component, therefore we anticipate developing and announcing this aspect of the program in FY 1990 with initial funding in late FY 1990 or early FY 1991.

d. At this time, no augmentations are assumed for any of the elements under the University Space Science and Technology Academic Program in FY 1991 and FY 1992.

Question 14: Dr. Fletcher, during your testimony on February 9, you indicated that if the space station research and development budget request was reduced by the Congress in FY 1990, the program would immediately slip.

a. Would the current schedule slip if the required personnel and facilities funds requested were not provided in FY 1990.

b. What are the current staffing levels of the Space Station Office, and what should they be? What levels are proposed for FY 1990?

c. How many additional people for the space station office are included in the operating plan change currently pending before the House and Senate Appropriations Committees? Is approval of this FY 1989 initiative critical to the current schedule?

Answer 14a: If the required personnel and facilities funds requested were not provided in FY 1990, a high degree of schedule risk would be introduced into the program. The extent of nay schedule slip would be determined after a thorough analysis of the entire available funding profile for the Space Station Freedom Program.

b. The space station staffing level planned for FY 1989 (all Centers) is 2,115 full time equivalent (FTE) personnel and for FY 1990 is 2,644 FTE. Additional staffing has been included in the operating plan currently pending before the Congress.

c. The current FY 1989 operating plan will enable initiation of hiring 200 FTE personnel. Approximately 132 FTE are for space station. Fiscal years 1989 and 1990 are crucial for the Space Station Freedom Program because preliminary design of all major elements and systems has begun and will continue. This significant activity cannot be adequately performed without the proper staffing. These additional personnel must be available if we are to meet the current schedule milestones leading to a First Element Launch (FEL) in the first quarter of FY 1995.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY SENATOR GORTON

It is my understanding that a substantial quantity of isotopes, primarily plutonium=238 (Pu=238), are required to power the Radioisotope Thermoelectric Generators used in NASA deep space probes. Documents submitted by NASA last year indicate that some space missions, including CRAF and Cassini, will need Pu=238 fuel by the early 1990's.

The Department of Energy's budget proposal for FY 1990 states that DoE will commission a study from the National Academy of Sciences on the site selection for the Pu=238 production. Should this study take too long, it could delay production of this necessary isotope until sometime in the mid-1990's, thereby jeopardizing NASA's schedule for these important space missions.

Question 1. Please explain the importance of Plutonium-238 to NASA's deep space missions.

Answer 1. Vitally important to deep space missions, Plutonium-238 is used to fuel radioisotope thermoelectric generators (RTGs), which are far more preferable to any other power sources in terms of safety, reliability, and longevity necessary for the Nation's deep (i.e., beyond 2 Astronomical Units) space missions. For example, since a mission to Jupiter has to operate five times farther from the Sun than a similar mission in Earth orbit, the solar radiation reaching the Jupiter mission is twenty-five times weaker. To generate the amount of power needed, a spacecraft flying to Jupiter would need solar panels that were twenty-five times larger. Such a massive power system would add both prohibitive weight and complexity to the mission, in large part because the solar panels would have to be deployed and articulated to track the Sun while orbiting Jupiter. Further, solar arrays are susceptible to damage from Jupiter's radiation belts.

Conversely, RTGs are lightweight, compact, highly reliable, and are immune to damage from radiation belts. RTGs currently provide power to Pioneers -10 and -11 launched in 1972 and 1973, respectively, and to the two Voyagers launched in 1977. Even for missions targeted for other outer solar system bodies, plutonium-fueled RTG immunity to Jovian radiation is important because a Jupiter swingby is often used to gain energy and momentum to reach those bodies beyond Jupiter.

Question 2. How much Pu-238 will be required to meet NASA's scheduled and anticipated future NASA mission over the next decade?

Answer 2. The CRAF-Cassini program will require approximately 41.5 kg of Pu-238 to function. The estimate is based upon 10 kg of new Pu-238 to fuel one CRAF flight unit, 10 kg Pu-238 for a shared CRAF-Cassini spare, 20 kg Pu-238 for two Cassini flight units, and 1.5 kg for radioisotope heater units.

Potential future solar system missions, which may be initiated in the late 1990's, include a sample return from a comet and Mars. The total amount of plutonium needed for the these future missions is still under study, but preliminary estimates indicate a range of 46–70 kg.

Question 3. Please provide a detailed schedule of when Pu-238 is required to satisfy NASA mission requirements?

Answer 3. NASA and the DoE are in the process of formulating a detailed schedule for delivery of Pu-238 to meet NASA mission requirements. We estimate that such a schedule will be available in the near future. NASA will supply a copy of the schedule as soon as it is available.

Question 4 If Pu-238 is not available to NASA until the mid-1990's or later, what will be the consequences for NASA space missions?

Answer 4. If Pu-238 is not available to NASA until the mid-1990's or later, the consequences will be serious disruption and delay to the Nation's planetary science effort. The President's FY 1990 budget request contains the CRAG-Cassini Program initiative to study the origin and early evolution of the solar system. In this program, NASA will launch the Comet Rendezvous/Asteroid Flyby (CRAF) mission in August 1995 and the Cassini (Saturn Orbiter Titan Probe) mission in April 1996. RTG's for those missions must be delivered six months prior to launch, and fuel production must begin approximately four years prior to RTG delivery.

If plutonium fuel is not available until the mid-1990's, the U.S. solar system exploration program will be further disrupted just as the program is recovering from its present hiatus. Such a delay would provide an opening for other nations to assume a leadership role in outer solar system explorations, an arena where the U.S. is presently unrivaled.

Question 5. How do you communicate your needs to the Department of Energy? Are you satisfied that your requirements are adequately addressed and that NASA is sufficiently involved in decisions related to the production of required materials?

Answer 5. NASA communicates its plutonium needs to DoE through continual dialogue at staff levels and by periodic transmission of updated strategic planning information. The Strategic Plan for the Office of Space Science and Applications (OSSA) is updated annually; as part of that plan, the strategic plan for Solar System Exploration is also updated annually. These plans are forwarded to DoE in condensed version for use in its own planning, particularly with regard to plutonium use and distribution.

NASA is satisfied that its requirements are sufficiently addressed by DoE, but we recognize that DoE has many, sometimes conflicting, requirements. Since the DoE is the only established source for Pu-238, DoE's plutonium production policies are of vital concern to NASA.

NASA AUTHORIZATION

THURSDAY, MARCH 16, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:35 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The subcommittee will come to order.

I would like to welcome our witnesses and guests. Today, we will review the Administration's budget request and the current status of the space station program.

Today, we will try and compile a record for the space station program that will help us argue for it as a budget priority in the turbulent days ahead.

With the return to flight of the space shuttle, the space station now takes on new meaning and enhanced importance as the next major element of this nation's space infrastructure.

The road back to flight status for the space shuttle has not been easy, and the road ahead for the space station will be just as challenging.

But try we must, and succeed we must, for all roads to the future do begin with the Space Station Freedom, as has been said.

As the members of the subcommittee and most of the audience know, the space station program has had to fight stormy seas since the program set sail in January of 1984. Tight budgets and new programs do not go together well, especially when the crew of the ship want to sail for 10 different ports.

During the past few years, the Reagan space station program was beset with interagency feuding and alternative agendas. With the exception of NASA and the President, the program had a limited base of support in the Administration. Despite this situation, NASA made progress in the definition activities. And NASA and the State Department made progress with international agreements and memoranda of understanding with our international partners: the European Space Agency, Japan and Canada.

But the real challenge to the program continues to persist: the budget. In the Gramm-Rudman-Hollings era, it is very difficult to get additional funding for any program or any agency. Therefore, an augmentation of $2.4 billion for NASA in fiscal year 1990, including an increase of $1.15 billion for the space station program and additional increases in the out years, will be very difficult. But as expensive as the space station program is, and as hard as it will be to get a large budget increase, we cannot afford not to provide the funds.

The choices we make this year will determine the status of our nation's space program for the decade of the 1990s, not just for fiscal year 1990. The choice we will make this year is not between funds for space station or no funds, it is really a choice between leadership or decline.

Today, we will start our review of the space station program by asking a lot of hard questions of our distinguished witnesses. By the end of this hearing, hopefully, we will have the answers we need as advocates of this challenging initiative. And I do view myself as an advocate.

At the outset, I would like each of the witnesses to know that I strongly endorse this program, but that each of you must work harder to make the case for the space station program as a budget priority, as a foreign policy priority, and as a technological leadership priority.

In the last few weeks, the subcommittee has received 500 letters concerning LANDSAT funding of $9.4 million. And only one letter concerning space station funding of $2.05 billion. Need I say more?

Well, next, we all need to work together to convince the President to fight for this program. In my opinion, If we must have a space station, as President Bush told a joint session of Congress, we are going to need presidential leadership.

In the past, that has been lacking. If it is lacking in the future, then there is no future. The challenge is ours and the challenge is today. Hopefully, with your help and with the testimony we receive today, we will be able to respond to the challenge and to initiate the next logical step in space, in earnest, in fiscal year 1990.

Again, I want to welcome all of you. And I want to recognize my distinguished colleague, the Senator from Virginia and friend, Senator Robb.

Senator **ROBB**. I was not planning to make an opening statement, Mr. Chairman.

Senator **GORE**. That is fine.

Senator Pressler has an opening statement that he would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY SENATOR PRESSLER

Mr. Chairman, I would like to thank you for calling this hearing today. No issue is more important to NASA and the future of the space program than the Space Station "Freedom" Program.

A permanent manned presence in space is essential if we are to go to Mars, a goal we all share. The polar platforms will be a critical part of our effort to gather data on the major environmental issues such as the greenhouse effect. These data will allow scientists to find bold solutions to these difficult problems. The unique microgravity environment will provide a laboratory that will allow us to make breakthrough discoveries in life sciences and materials research.

The future of the space program depends on the deployment of the space station. We must have it if we are to be a leader in space into the next century. Last fall we made a commitment with our Japanese, Canadian and European allies to proceed with this program on a cooperative basis. I believe that we must honor this commitment and proceed apace with funding for the space station. And, I believe that we must honor our commitment to pursue a course of excellence [illegible]r the future. This will require reaffirmation of cutting edge programs such as the space station as a national priority.

Mr. Chairman, we often hear the complaint that NASA lacks vision and has no long-term goals. I beg to differ with that assessment. NASA faces an uphill battle to receive the funding needed for the space station. And this will be a pivotal year for the program. I believe that we should commit ourselves to the short-term goal of getting full funding for NASA and the space station. Without the space station, there need be no debate about future options and missions. We will have answered that question already.

Senator GORE. Let me invite all of our witnesses to proceed with the assurance that your prepared remarks will be included in the record in full. You may present a summary or all of your remarks as you see fit.

And we are going to begin with you, Mr. Odom, associate administrator for Space Station with NASA. Welcome. We are glad to have you here today.

You are accompanied by Mr. Raymond Tanner, director of the Space Station Freedom Program Office and Mr. Anderson.

Mr. Anderson, would you introduce yourself for the record?

Mr. ODOM. Mr. Anderson headed up the Program Control Office that put this budget together and submitted it to you, Mr. Chairman.

Senator GORE. Very good. Well, go ahead, Mr. Odom.

STATEMENT OF JAMES B. ODOM, ASSOCIATE ADMINISTRATOR FOR SPACE STATION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY RAYMOND TANNER, DIRECTOR, SPACE STATION FREEDOM PROGRAM; PAUL ANDERSON, DIRECTOR, INSTITUTIONAL RESOURCES ANALYSIS OFFICE

Mr. ODOM. Thank you, Mr. Chairman. And as you indicated, I would like to submit my full testimony for the record. But what I would like to do is just very briefly give you a few of my own convictions about this program that I think are important, and I think are indicative of the significance of our program, just as you have aptly stated also.

So, I would like to get right into that. The first conviction Mr. Chairman, is that the Freedom program is an extremely important component of our U.S. objectives for the future, both terrestrially speaking and space speaking.

I think a permanently manned civil space station for peaceful purposes and within international law is an investment that we can ill afford not to make. I think it will contribute to our technological leadership both on Earth and in space.

I think it will also enhance our national competitiveness, and I think that is obviously important. It also promotes stronger ties with our friends and allies, for Freedom is the largest cooperative science and technology project that has been undertaken to date by man.

My second conviction is that the Space Station Freedom will result in a broad set of important benefits to the nation.

Senator GORE. Mr. Odom, so you will not feel any discourtesy, we are voting in the Armed Services Committee on Congressman Cheney to be Secretary of Defense. So I will be momentarily disposed to go there. And I will leave you in the capable hands of Senator Gore.

Mr. Odom. Thank you, Mr. Chairman.

Senator Robb [presiding]. Please continue Mr. Odom.

Mr. Odom. As I said, I think the Space Station Freedom will result in a broad set of benefits for our nation. It is certainly a key element of the space infrastructure, as the chairman just indicated. This is something that is not a mission in and of itself, but it is a facility, it is a capability to provide permanently manned capability in space.

As we said earlier, it is a key element of that total infrastructure in the civil space program. It will support new research and applications such as life sciences, material sciences and Earth observation, just to mention a few. It also will be a test bed for their technologies prior to their application and utilization both in space and on Earth.

It will also be a permanent outpost, a place for the future exploration missions, a necessary building block, independent of where we choose to go, whether back to the Moon or to Mars.

However, benefits are not limited to space. Education is an extremely important aspect of our activity and of yours also. It will strengthen the interest of our children in science and technology and mathematics, and will tend to revitalize our U.S. university science and technology programs.

It also, I think, is appropriate for us to recognize that the people that will utilize and operate the Space Station Freedom are in schools today. It will provide advances in key technologies and technology spinoffs and results. And also will make our Nation more competitive. The investment now, I believe, as has been in the past, will pay tremendous dividends and benefits in the future.

My third conviction is our that leadership in space will not go unchallenged. The Soviet program, is not the only one that we should be worried about. The Soviets already have a space station in orbit. They will have probably their third-generation space station in 1994, or a year before we start to assemble ours.

Other countries also have extremely ambitious programs, not only in unmanned satellites, but also in manned programs.

As President Bush said, our commitment to leadership in space is symbolic of the role that we seek in the world. I also applaud the President's comment relative to the necessity of the Space Station Freedom in his discussion with the shuttle crew this morning.

My fourth conviction: Our plans for Freedom are well laid, and our program is making real progress. We have the right development organization, the right management structure in place. We also have the right configuration that has resulted from our years of Phase A and Phase B studies.

The program truly is underway and on the same schedule and cost plan that we told you last April. We are also designing and testing hundreds of hardware items, literally as we speak. We are building and testing some prototype development hardware that is proving very, very productive, that has come from our past research programs and technology programs. And those hardware, many of those, literally hundreds, are in test today. The space station heat pipe experiment is currently on going on the space shuttle that is up today. Life cycle cost will be an extremely major portion and a key element of this program, more so than in any other program that we have undertaken.

Our international partners have made very strong commitments, and expect the same from us. As you recall, we signed the Intergovernmental Agreements and the Memoranda of Understandings with all of the countries, with the exception of the MOU with Japan, last September, and we signed that last MOU on Tuesday of this week.

Now all of our commitments are formalized with our partners.

My last conviction: Cutting corners at this point I believe would be unacceptable and poor stewardship on all of our parts. Underfunding again would cause other delays and content reductions, which would slash the space station capabilities, increase the program risks and reduce its productivity.

Dollars saved today will cost us more dollars later in higher development and operating costs. We plan to use the space station through the first quarter of the next century. Consequently, we must do it right.

In conclusion, I think the Freedom is an essential element of our U.S. national objectives. We, as a nation, made the right decision and the right choices over the last years, relative to this program. Space, has many times over proven to be a worthwhile investment in the years past.

We have a responsibility to look toward the future. And the Freedom is an important part of that future.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF JAMES B. ODOM, ASSOCIATE ADMINISTRATOR FOR SPACE STATION, NASA

Mr. Chairman and Members of the Subcommittee,

I am pleased to be here today to discuss NASA's recent accomplishments on the Space Station Freedom Program -- they have been significant. I will describe these accomplishments in detail, as well as identify work now in progress. Finally, I will discuss NASA's budget request, focusing on the important activities for which these funds are required.

Let me begin, however, by emphasizing that the reasons why our nation is building Space Station Freedom are now more relevant than ever. Last year's successful return-to-flight of the Space Shuttle was an important step toward reinvigorating American leadership in space. With Space Station Freedom, safe and effective operation of the space shuttle, and programs such as the Great Observatories, we are ensuring that the United States maintains this leadership through the late 1990s and well into the next century.

A permanently manned base in orbit is vitally necessary for our nation to sustain this leadership and to continue reaping its associated wealth of benefits. The importance of this program has been repeatedly recognized in Presidential and Congressional decisions to proceed with Space Station Freedom and keep the program on track. President Bush reiterated this recently when he said, "We must have a manned space station... the space program should always go 'full throttle up.' That is not just our ambition; it is our destiny."

The benefits of our leadership in space and federal investments in space research and development have been very tangible - they have enhanced our national science and technology base and contributed to our economic well being. As an investment in the future, Space Station Freedom is no exception. I am convinced that people will play a productive role in space, just as they do on Earth. The capability to live and work in space laboratories and workshops on a continuous basis, 365 days a year, will result in significant benefits.

Space Station Freedom is the next step in the development of our national space infrastructure. Just as railroads played a central role in opening the American frontier for development after the initial exploration, this infrastructure will be the foundation to open the frontier of space for development.

As a cornerstone of this infrastructure, Space Station Freedom complements capabilities and objectives across all parts of our space program. For our science program, Freedom offers platforms for instruments to look out at the universe as well as back toward the Earth, and a laboratory for research in many scientific disciplines. Long term operation on the manned base or its associated platforms will be a natural growth path for scientific experiments developed on the ground and flown on the Space Shuttle or privately developed facilities. For technology development, Freedom will be a unique national facility - a testbed for evaluating technologies, procedures, and design approaches for potential application in future space systems. Technology benefits may even begin to flow before Freedom is operational in such important areas as control of large space structures, power generation, automation and robotics, and environmental control. For our exploration program, Freedom's manned base represents the establishment of a permanently manned outpost in space.

Freedom will initially be most valuable as a space workshop, laboratory, and viewing platform. As our leadership and vision continue and as national requirements are defined, it can evolve to accommodate other potential roles: a "construction facility" for assembling large space structures, a "service station" for satellite refueling and repair, and a "production facility" for unique materials and substances.

The long term goal of expanding human presence and activity beyond low earth orbit requires the space station for potential missions to the moon, Mars, or other parts of the solar system. Initially, we will use the manned base to study the long-term effects of the space environment on people to prepare us for the potential missions of the future. Before we take this step, we must understand the effects of weightlessness in humans, and develop countermeasures to prevent any detrimental effects. Freedom may one day be our waystation in orbit, a staging area for manned expeditions venturing out from our home planet to explore other parts of the solar system. No matter what major objectives we choose for the early 21st Century, Freedom is a necessary stepping stone. NASA's Office of Exploration succinctly captured the importance of this fact in a single phrase in its 1988 Annual Report: "All roads begin with Space Station Freedom..."

When our presence in space matures from short visits to prolonged stays, the inherent nature of research in space will change, facilitating not only the normal process of scientific investigation, but also the totally unexpected - and sometimes serendipitous - discoveries that have historically been so important to technological advancement. Moreover, the human innovative spirit will be unleashed from the constraints of limited time and experience in this new environment. Advances in space technology, materials science, life sciences, and biotechnology will probably be the first visible dividends we earn, but there will be many, many more.

The program will have a positive motivational influence on education. Freedom's high public visibility and our educational programs will revitalize interest by our young people in science and engineering careers. Furthermore, the capability to conduct rapid response experiments in reaction to new ideas and research opportunities will have a positive impact on university students and researchers, particularly those pursuing advanced degrees. All of these factors will act to strengthen our national technological competitiveness and long-term economic well-being.

At a higher level, Space Station Freedom will offer benefits that transcend the objectives of any single nation. Freedom will not only become a global focal point for space research, it will also help us better understand the world in which we live.

This role becomes increasingly important as world interest in global environmental changes grows more urgent. Space Station Freedom's capabilities will support the U.S. Global Change Research Program to examine closely the impact of environmental changes on our planet. Global problems such as deforestation, desertification, ozone depletion, and climatic shifts will be studied by instruments on both the manned base and its associated polar platforms.

When President Reagan called for the development of the space station, he invited international participation to strengthen peace, build prosperity, and expand freedom for all who share our goals. After three years of intensive negotiations, our partners (Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, and the United Kingdom) are providing major program elements estimated to cost nearly $8 billion, making Freedom an unparalleled effort in international science and technology cooperation. At the Intergovernmental Agreement signing ceremony last year, former Secretary of State George Schultz noted that "this project also will be a shining symbol of the commitment of those who place a high value on political and economic freedom to cooperate for mutual benefit."

President Bush, like President Reagan, recognizes that space holds enormous potential for commerce. He supports private sector investments in space with specific policy guidance and instructions. We are actively seeking private sector involvement in the program through two distinct avenues: commercial utilization of Space Station Freedom and commercial provision of program-related infrastructure. The innovative strengths of American industry can make a substantial contribution to our space activities. This will be covered in more detail later in the testimony.

We have already made significant progress toward achieving the objectives I have described thus far. A strong management structure, tailored to handle the complexity of the Freedom program, has been established. We have confirmed that our configuration is the correct one to meet our national objectives. Freedom's team of contractors, most of whom have worked on the program for four to six years, is now engaged in design activities. Last, the program is on schedule and projected costs remain unchanged.

It is essential that Space Station Freedom program activities continue to be fully funded if our early efforts to build a proper program framework are to result in substantial savings in the years ahead. Total life cycle cost factors are at least as important as development costs in design decisions. Similarly, we will continue to place a strong emphasis on ensuring that user needs are addressed during the design process. These early efforts, which will later enable us to achieve the maximum benefit from Space Station Freedom for the lowest reasonable cost, must continue unimpeded.

* * * * *

Program Status: Recent Accomplishments and 1989 Activities

I would now like to move on to our recent progress and ongoing activities.

An effective development structure for the Freedom program is now in place. Last September, NASA signed contracts with the four work package prime contractors. Boeing is working with the Marshall Space Flight Center to develop the U.S. pressurized modules and logistics elements. McDonnell Douglas is working with the Johnson Space Center to develop the central truss structure, resource nodes, and various flight systems. General Electric is working with the Goddard Space Flight Center to develop the Polar Platform and attached payload accommodations on the manned base. Rocketdyne is working with the Lewis Research Center to develop elements for power generation, storage, and distribution.

To enable the long-term intersite delivery process and to reduce program risk, Associate Contractor Agreements have been instituted among these companies. These agreements facilitate direct interaction in resolving detailed interface and scheduling problems before products are delivered. The resulting increase in efficiency will minimize costs, reduce program risks, and allow better use of resources.

We also have in place three contracts that are important components of the development structure required to successfully address the complex management and technical issues of the program. These efforts, managed by the Space Station Freedom Program Office in Reston, are just as essential to the success of the program as the development contracts.

The Program Support Contractor, Grumman, performs critical systems engineering and integration tasks for the program office. This contractor also plays key roles in supporting program management processes, in laying groundwork for operation planning, and in interactions with the user community.

Lockheed is developing the Software Support Environment, an integrated set of standardized software "rules and tools" that will simplify the development, operation, and maintenance of computer programs used in both flight and ground systems over the life of the Freedom program.

Finally, Boeing is developing the Technical and Management Information System. This system and associated services will provide a conduit and storage resource for the virtual flood of information that will flow among hundreds of organizations during Freedom's development and 30-year life.

An intensive review by the National Research Council in 1987 confirmed that our baseline configuration is the best design suited to meet the overall requirements. The report stated that the configuration "reflects the thoughtful compromises among the priorities and sometimes conflicting requirements of its early scientific and engineering users." Last year we formally defined space station system and element requirements so that preliminary design activities could begin. A program-wide requirements review, held in the early summer, was followed by more detailed requirements reviews at the NASA Centers responsible for the four work packages. The objective of these efforts was to ensure that critical design requirements throughout the program were identified, quantified, and reflected consistently in documentation at all program levels.

With these important milestones behind us, our development efforts are now underway. The four NASA work package centers and their prime contractors are now heavily involved in design activities for their assigned Space Station Freedom elements and systems.

Our advanced development program for some critical hardware is beginning to show some return, and we are seeing tangible results. Prototypes of the rotary joints that will point the solar arrays and thermal radiators have been fabricated by Honeywell and delivered to Johnson Space Center for testing. A prototype of the control moment gyroscope needed for attitude control was built by Allied-Signal and will shortly undergo life testing at Johnson Space Center to verify the design and evaluate new features. Substantial work has been performed by Marshall Space Flight Center and its contractors on the environmental control and life support system. Selected elements of this system have been built, several new technologies for waste management have been developed, and tests are now in progress to measure their effectiveness in an environment similar to that planned on Freedom. In the area of automation technology, Goddard Space Flight Center is continuing its work on advanced robotic manipulators. At the Lewis Research Center, nickel-hydrogen batteries are undergoing life cycle tests to provide data needed for their use on Freedom. Testbeds to demonstrate the operation of a 20KHz power management and distribution system have been built. Hydrogen/oxygen thrusters and resistojet thrusters are also being tested.

Utilization and operations planning is an extremely important ongoing process in the design of the station because it ensures that user requirements are properly incorporated and that the manned base and polar platforms can be effectively operated over the long term. Working together with the user community and our partners, we are defining the detailed requirements for a wide variety of user activities. Workshops were held last year to exchange information on science operations, user accommodations, ground processing and related topics. On-orbit operations and maintenance concepts are being defined to influence system design. Additionally, long term logistics support has been incorporated as a major driver in system design and acquisition decisions.

Two important facilities for Space Station Freedom were recently completed to support ongoing hardware development efforts. The Space Station Mockup and Integration Facility at Johnson Space Center was dedicated in November. The Power Systems Facility at Lewis Research Center was dedicated this January.

In September, the U.S. Secretary of State and representatives of Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, and the United Kingdom signed the Intergovernmental Agreement covering cooperation in the Space Station Freedom Program. This monumental agreement will be the foundation for three decades of international space station activities. Robert de Cotret, who signed the agreement on behalf of Canada, aptly stated, "today is the fusion of two modern trends as one, when several nations agree to work together in the peaceful exploration of the universe that surrounds our globe. In doing so, we make for a better world here on Earth."

NASA also signed separate bilateral Memoranda of Understanding with the European Space Agency and the Canadian Ministry of State for Science and Technology that focus on programmatic and technical aspects. We will sign a similar agreement with Japan this spring. These agreements, coupled with the strong budget commitments of our international partners, represent long term commitments to the success of this program.

With the negotiations behind us, we have moved to the implementation phase of the cooperation. We are working with our partners to establish the management mechanisms created in the Intergovernmental Agreement and the Memoranda of Understanding. We are also developing the second-tier documentation called for in our agreements. Our partners have established liaison offices here in the United States, and we are completing the establishment of similar offices in our partners' countries. These liaison offices are critical to working with our partners effectively and efficiently.

Earlier this month, NASA announced the selection of scientific investigations for definition in the Earth Observing System program. This effort to study global environmental changes will utilize instruments on polar orbiting platforms, beginning with the Space Station Freedom Polar Platform. The selected teams' activities will involve 551 investigators from 168 institutions, universities, and laboratories in 32 states and 13 nations.

To encourage and promote commercial participation in Space Station Freedom infrastructure, we released draft policy guidelines, procedures, and criteria for industry review last October. This document will be revised and formally issued after industry comments are received this year. Additionally, in 1989 we plan to establish a process for identifying future space station requirements that could be commercially provided, along with implementation mechanisms consistent with Administration policy and procurement regulations.

In November, we co-sponsored with the Office of Commercial Programs our second successful workshop on commercial opportunities in the Space Station Freedom Program. Potential opportunities in materials sciences, remote sensing, life sciences, and infrastructure were discussed with 150 industry representatives. This workshop will be held annually.

We are still on schedule for the major program milestones, including the first element launch in the first quarter of 1995, man-tended capability in the fourth quarter of 1995, permanently manned capability in the fourth quarter of 1996, and assembly complete in the first quarter of 1998. These dates are the same as those presented to you last year.

Finally, I want to note that our estimate of total runout costs for the Freedom development effort remains at $13 billion in 1984 dollars. In summary, the program has stabilized. The configuration has been set since 1987, and our cost estimates and schedule remain the same.

We have been able to maintain our schedule and cost plans only because Congress and the Administration have strongly supported the build-up in funding levels that is essential to a program of this scope. You demonstrated this support last year when you approved a three year authorization for the Freedom program. Your continued support is absolutely imperative if Space Station Freedom is to be built cost-effectively and on time.

* * * * *

Budget Request For Fiscal Year 1990

The funding required for Space Station Freedom in FY 1990 represents a substantial increase over this year's funding. This increase is necessary if we are to design and build the right station, on schedule and at the overall funding level we have set. To support the design process that is now underway for most Freedom elements and components, our contractors' engineering work force must be expanded considerably, and subcontractors must be brought on board as planned. In addition, ground facilities required for testing, training and integration must be completed in order to support the schedule. Total aerospace-related jobs associated with the Space Station Freedom Program are estimated to increase from 15,000 to 32,000 across the country.

$2.050 billion is required to keep the Space Station Freedom Program moving forward in FY 1990.

Of this total, $1.556 billion will go to the four work package centers in order to pay for the required buildup of development activities at the four prime hardware contractors and their subcontractors. The NASA centers will continue to use their expertise and facilities for supporting development activities such as test bed construction and operation, in-line hardware development and supporting analyses, safety reviews, and quality assurance.

$184 million will go toward operations and utilization capability development. This effort includes the design and development of equipment, facilities, and capabilities required to operate and use Space Station Freedom efficiently and effectively.

$230 million will be spent to integrate the program's management and technical systems, to perform systems engineering, to coordinate activities with our international partners, to implement a software environment directed at controlling software costs, and to enable other program control and support activities.

$15 million will be spent on the Flight Telerobotic Servicer (FTS). Consistent with Administration policy, NASA is exploring private investment in development of the actual flight hardware, so the funds we request at this time are only for activities at the Goddard Space Flight Center that support development.

$25 million will be required for the Transition Definition Program to ensure that Space Station Freedom is designed to easily incorporate new capabilities to enhance utility, improve efficiency of on-board operations, support commercialization efforts, and meet future national objectives.

$25 million will be needed for Operations. Although some planning for operations is ongoing within the development program to ensure that user requirements are adequately addressed in the space station design, FY 1990 is the first year that funding is required to plan for integrated logistics operations and space systems operations in the program's actual operations budget.

Finally, $15 million is required for a new item in the program, a radar system to detect and monitor orbital debris. This effort, funded by NASA's Office of Space Flight prior to FY 1990, will provide data needed to ensure that the Freedom manned base will be adequately protected from debris impact.

In addition to the funding I have just discussed, the Administration proposes legislation for a three year advance authorization and appropriation of $8.5 billion covering FY 1990, 1991, and 1992. A program development cost ceiling of $13 billion in 1984 dollars is also proposed. This legislation would, by increasing programmatic stability and continuity of funding, facilitate resource planning and improve the cost-effectiveness of the development process.

* * * * *

Fabrication and test of the propulsion system water electrolysis prototype will continue, and refinement and testing of an advanced space suit will be completed. Tests requiring a zero-gravity environment will be carried out on the KC135 aircraft, which can provide short periods of low gravity test time.

Work Package 3

Goddard Space Flight Center and its prime contractor, General Electric, will complete preliminary design of Work Package 3 elements and systems. These include the U.S. Polar Platform and attached payload accommodations, including a payload pointing system. Preliminary design reviews will be conducted to allow final design activities to get underway.

General Electric will also continue studies of servicing facility architecture, and will develop servicing scenarios for selected payloads located outside the pressurized modules.

Goddard Space Flight Center will continue its supporting development activities. The effects of space station motion on the payload pointing system will be studied. As part of the attached payload and polar platform thermal control program, development of a data management system test bed and an instrument test bed will continue, as will design of several experiments planned for flight on the Space Shuttle. Requirements definition and design of the planned Integration, Test and Verification Facility will be initiated. This facility will provide a clean environment for the check-out of attached payloads and the polar platform with the appropriate physical, electrical and thermal interfaces.

Work Package 4

Lewis Research Center and its prime contractor, Rocketdyne, will complete preliminary design of Work Package 4 elements and systems. These include power modules and other parts of the electrical power system. Preliminary design reviews will be conducted to allow final design activities to get underway.

Rocketdyne will also continue development and qualification of photovoltaic cells and substrate blankets. Qualification nickel-hydrogen energy storage assembly cells will be fabricated and tested. The preliminary design effort for the solar dynamic power system will continue. Development and testing of the 25 kW, 20kHz primary distribution breadboard and brassboard will continue.

Lewis Research Center will continue its supporting development efforts. Prime contractor systems engineering and integration efforts will be independently verified. Work on the photovoltaic power generation and storage and power management and distribution elements will continue, using several existing testbeds, and an integrated testbed will be built. Activities to support the solar dynamic power development effort will include thermal-vacuum testing of an advanced development heat receiver and optical testing of a solar concentrator.

In addition to the activities I have just described, each work package will be involved in many other significant activities. Continuous update of interface control documents will be crucial as system and system component designs mature. Each work package will also support development of the distributed systems that interface across more than one work package. Procurement of long lead items will also begin.

Operations / Utilization Capability Development

This effort spans activities at several NASA centers. The Program Office will continue to develop the tactical planning capabilities required for integrated operations and utilization activity planning during the assembly and operations phases.

The Kennedy Space Center will continue to develop capabilities for pre-launch and post-landing ground operations. Equipment for computer-aided design and computer-aided engineering will be procured, design of the Test, Control, and Monitor System will continue, and equipment for the Space Station Processing Facility will be procured. Marshall Space Flight Center will continue developing user integration capabilities. Design of the Payload Operations Integration Center and the Payload Operations Training Facility will continue, and analytical integration software tools will be developed. Johnson Space Center will continue to develop capabilities for operational control of Space Station Freedom. Design of the Space Station Control Center and the Space Station Training Facility will continue. Goddard Space Flight Center will continue user accommodation studies.

Each of the NASA Space Station Freedom development centers will also continue design of an Engineering Support Center to provide technical expertise during the assembly and operational phases of the program.

Systems Engineering, Integration, and Management

A program-wide preliminary design review will be conducted in the summer of 1990. In preparation for this review, the Program Support Contractor, Grumman, will conduct numerous integrated systems analyses to support the establishment of detailed design requirements for the work package contractors and the evaluation of end-to-end performance of their designs when integrated together into the space station.

Specific analytical efforts will include combined loads analyses, combined thermal system loading and performance studies, and assessments of the natural and induced particulate and electromagnetic environments around Space Station Freedom. The performance and interaction of designs for all distributed systems will be analyzed for each of the twenty on-orbit assembly sequence configurations as well as for contingency situations.

The Program Support Contractor will also play a key role in the development of program plans for launch package integration, on-orbit assembly and checkout, mission planning and integration, system safety plans, and quality assurance plans.

Operations

As the Space Station Freedom Program matures, elements of the development program (including operations/utilization concept development) will transition into components of the operations program. This transition will begin in FY 1990. Initial planning for integrated logistics operations will focus on logistics management, maintenance planning, and early planning for initial spares. Space system operations activities will include the study and integration of assembly planning tasks.

Transition Definition

Because Space Station Freedom will have an operational lifetime of 30 years, which is unprecedented for a space system, it must be designed to adapt to support evolving user needs. Moreover, elements and systems must easily accommodate future technology advances to enhance

Activities Supported By FY 1990 Funding

Let me now move into the specifics of what we must accomplish in FY 1990 to maintain our goal of launching the first elements of Freedom in the first quarter of 1995. I will first describe development and supporting development activities for the four work packages, then move on to other work planned for FY 1990.

Work Package 1

Marshall Space Flight Center and its prime contractor, Boeing, will complete preliminary design of Work Package 1 elements and systems. These include the U.S. laboratory module, the habitat module, logistics elements, the environmental control and life support system (ECLSS), the resource node structure, and internal components of the audio/video and thermal control systems. Preliminary design reviews on these items will be conducted to allow final design activities to get underway.

Boeing will also complete comparative testing of ECLSS technology demonstration hardware and will begin testing in the Core Module Integration Facility, a full-scale mockup of the U.S. laboratory module. Work on resource nodes and airlock systems will focus on component testing of support equipment, preliminary design of the cupola, tool and production planning, and material procurement for structural test articles. Boeing will complete the U.S. laboratory engineering development article, and fabrication and test of development hardware and software will begin. Preliminary design of functions unique to the habitation modules will continue, as will the review of cargo requirements for the logistics modules. Concepts will be developed for the accommodation of specimens, carriers, and subsystems. Development testing for logistics-unique hardware and definition of logistics module interfaces with the cargo, Orbiter, and space station will continue. Neutral buoyancy facility tests will be performed to evaluate and verify man-systems interfaces. The critical design review on the node structural test article will be conducted, leading to the start of fabrication.

Marshall Space Flight Center will continue its supporting development efforts. Breadboards (hardware assemblies of preliminary parts used to prove hardware feasibility) will be used for development testing for the process-material management system, the audio-video system, and the electrical system. By the end of FY 1990, most of the supporting development testing will be completed and the prime contractor can begin building flight-design hardware for qualification testing.

Work Package 2

Johnson Space Center and its prime contractor, McDonnell Douglas, will complete preliminary design of Work Package 2 elements and systems. These include the central truss structure, mobile transporter, propulsion system, outfitting of resource nodes, airlocks, guidance, navigation and control system, external components of the thermal control system, communication and tracking system, data management system, and systems for extravehicular activity. Preliminary design reviews on these items will be conducted to allow final design activities to get underway.

McDonnell Douglas will also continue development testing and begin procurement, fabrication, and assembly of data management system hardware and software, the thermal control system, the mobile transporter, and the airlocks. Development of the propulsion system electrolysis unit, propellant tanks, and thrusters will be initiated.

Johnson Space Center will continue its supporting development efforts. Integrated loads/dynamics analysis of the Freedom truss structure will begin, a thermal vacuum chamber will be outfitted for solar simulation, and verification testing of the TDRSS on-board antenna will be conducted.

productivity, reliability, and safety as well as to avoid obsolescence. For this reason, evolution planning and advanced technology development have already begun.

Evolution planning has already resulted in better definition of the resource requirements and primary design features (software hooks and hardware scars) required to accommodate evolution in the baseline design. In FY 1989, we are focusing on probable evolution paths and their impact on detailed hooks and scars in distributed systems. In FY 1990, we will begin feasibility studies on a reference configuration, and will identify the technologies necessary for evolution. We will also fund development work on the application of knowledge-based system technology to management of the distributed systems on the station. Other tasks will focus on automation technologies that could be applied to Space Station Freedom early in its operational lifetime. We will also continue to expand the efforts in planning for commercial participation in the space station.

Orbital Debris Radar

The development of the orbital debris radar will begin in FY 1990. This ground-based radar is required to gather new data on the orbital debris environment in which Space Station Freedom will operate. Since orbital debris is a potential threat to all space systems, accurate characterization of this environment is a necessary input to the design of the pressurized modules. The orbital debris radar, unlike existing radars, will be able to track debris between one and ten centimeters in diameter. The Jet Propulsion Laboratory will manage the development of the required hardware and software, which will be developed under a competitive contract.

Flight Telerobotic Servicer

NASA is currently reviewing proposals from two companies, Martin Marietta and Grumman, for development of the FTS. Contract award is planned for June 1989. The FY1990 budget for FTS assumes that NASA will seek private sector investment in system development. However, NASA will continue its supporting development and integration activities.

Contractor activities in FY 1990 will focus on two near-term test flights planned for the Shuttle. Detailed design of equipment for the early telerobotics demonstration test flight will be conducted, and preliminary design activities for the early development test flight and the Space Station Freedom flight article will begin.

Goddard Space Flight Center and other NASA centers will continue their supporting development activities. Applicable new automation and robotics technologies will be selected to improve FTS performance.

* * * * *

I would now like to address two other issues associated with the FY 1990 budget request.

Commercialization

The NASA commercialization initiatives proposed by the Administration support national space policy and commercial space initiatives. President Bush reinforced the U.S. policy objective of more commercial development in space in his State of the Union message on February 9.

The specific commercialization initiatives for the Space Station Freedom Program include the FTS, the Space Station Processing Facility (SSPF), the Neutral Buoyancy Laboratory (NBL), the docking module, the logistics system, and potential enhancements like solar dynamic power.

The SSPF at Kennedy Space Center will be used for preflight processing of manned base hardware and both preflight and postflight processing of logistics elements. The SSPF was selected because of its potential for synergy with commercial proposals being considered by NASA in the area of logistics services. The private sector has already shown interest.

The NBL at Johnson Space Center will include a very large underwater working area for developing and practicing manned assembly approaches for Space Station Freedom. Existing facilities are too small to support the extensive activities planned. The astronauts who will assemble and maintain the manned base require intensive terrestrial training and preparation to maximize the safety, efficiency, and effectiveness of operations in space. The NBL was selected for commercialization because of its potential for long-term use by space station users and for terrestrial applications. The private sector has already shown interest. Potential commercial applications include preparation for undersea construction and maintenance activities, including those involved with offshore oil drilling.

The space station docking module was selected because commercial entities have indicated interest in developing it or are developing similar systems.

We will continue to explore ways to commercialize elements of the logistics system. Private sector proposals to participate resulted from our inclusion of the commercialization concept in the space station requests for proposals. We will continue to review with the Administration any significant issues that may arise.

The solar dynamic power enhancement for the space station could allow domestic firms to receive payment for the provision of power in space and to protect their technology for future applications.

NASA has been working on the development of specific criteria, guidelines, policies, and procedures to facilitate and encourage commercialization. These have been recently released for industry comment. We certainly seek Congressional views as well.

It must be recognized, of course, that commercialization decisions should consider the nature of the project involved, the stage of procurement, the nature and scope of commercial proposals, and resulting benefits to the government. Consequently, we will need to maintain flexibility in developing approaches to commercialization.

It should be noted that foreign competitors are moving ahead in space commercialization. Foreign companies, often in cooperation with their governments, are making investments to obtain financial benefits in the future. In Japan, for example, it is widely predicted that its space industry will be as important to its national economy in the future as its electronics industry is today. We in the government should be encouraging American companies to invest in our economic future in space as well.

The Space Station Manpower Problem

NASA's FY 1990 budget includes Research and Program Management (R&PM) funds for salaries of additional civil servants for Space Station Freedom. As the efforts of the space station contractors expand, NASA direction and oversight must also grow to ensure that Research and Development (R&D) funds are spent wisely and efficiently. The additional personnel requested for FY 1990 are required if we are to continue the strong management role necessary for effective systems engineering and overall direction of this international program.

In FY 1989, the Administration approved an agency-wide, multi-year staffing augmentation plan that included 725 additional civil servants to support the program at Reston and the work package centers. Our plan is to accommodate an initial increment of this augmentation in NASA's FY 1989 operating plan. NASA's FY 1990 R&PM request must be fully funded to adequately meet space station staffing needs.

* * * * *

Conclusion

In closing, I want to leave you with four important thoughts.

First, Space Station Freedom will result in a broad spectrum of benefits to the United States. Freedom is not a mission in itself. Instead, it is a unique capability that will yield significant technological, scientific, economic, social, educational and foreign policy benefits. Freedom is a vital piece of the space infrastructure our nation needs to support science, technology development and exploration efforts. We will depend on this valuable resource for decades to come. *Our investment now will pay tremendous dividends later.*

Second, our leadership in space will not go unchallenged. The future will belong to those who prepare for it and are committed to it, and the long term space plans of other nations are ambitious. Our commitment to Space Station Freedom is a commitment to U.S. space leadership, As President Bush so aptly stated, *"our commitment to leadership in space is symbolic of the role we seek in the world"*.

Third, our plans for Space Station Freedom are well-laid and our program is stable. The right management and development structure is in place. We have the right configuration given our objectives and funding constraints, and we have already made a significant national investment in its implementation. Our international partners are fully committed to their parts of the program. *We have made substantial progress and are well on our way.*

Last, cutting corners would be inefficient. Our budget for FY 1990 is just barely adequate. Underfunding Freedom at this critical phase of the program would reduce its performance, and thus its usefulness. At the same time, *it would increase program risk, and increase total long term costs.*

When we, as a nation, chose to proceed with Space Station Freedom, we made the right decision for the right reasons. We cannot back away from our commitment to this endeavor, for it is too important to our future as a space-faring nation. The American space program has proven over the past three decades to be among our wisest investments, inextricably linked not only to the economic welfare and vitality of our country, but also to the nurturing of our national spirit. We have an unavoidable responsibility to look to the future and its challenges, and Space Station Freedom is an essential part of the American future.

We must stay on track.

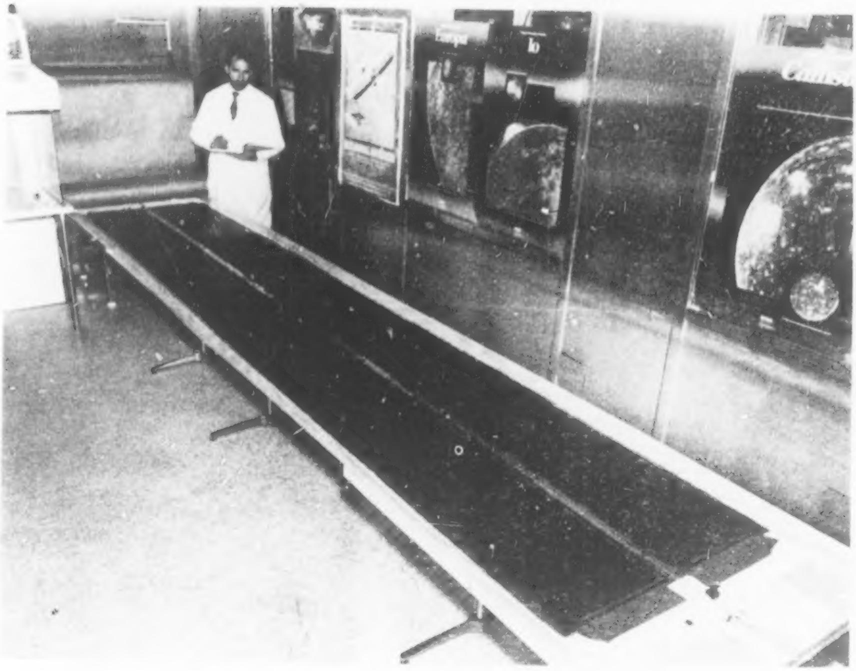


FIGURE 1.—Two electrically-active, solar array panels from a photovoltaic power module at Lewis Research Center.

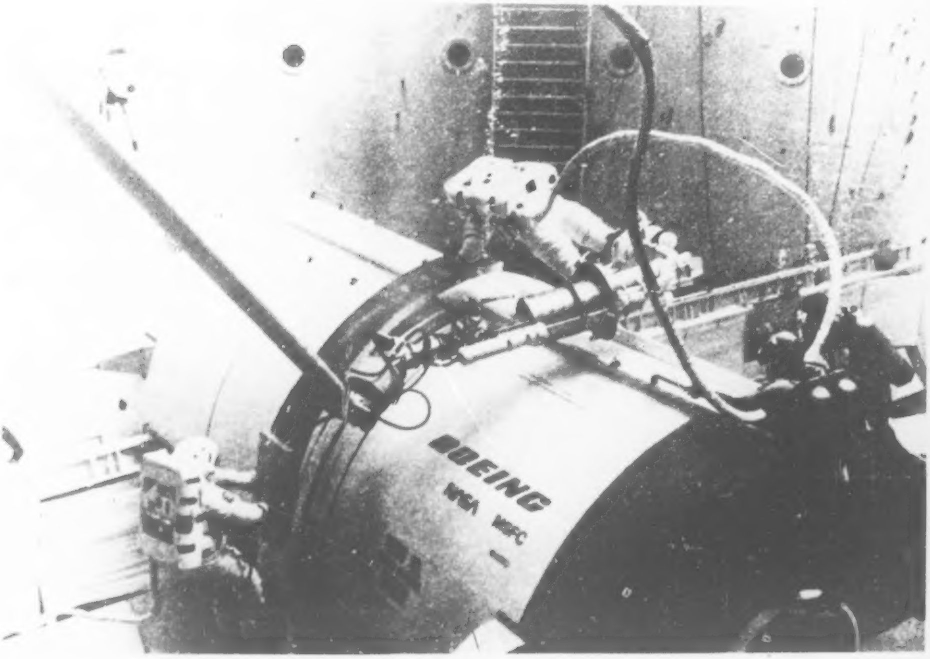


FIGURE 2.—"Astronauts" repair a combination heat radiator and debris shield mounted on a pressurized module mockup in the Marshall Space Flight Center Neutral Buoyancy Facility.

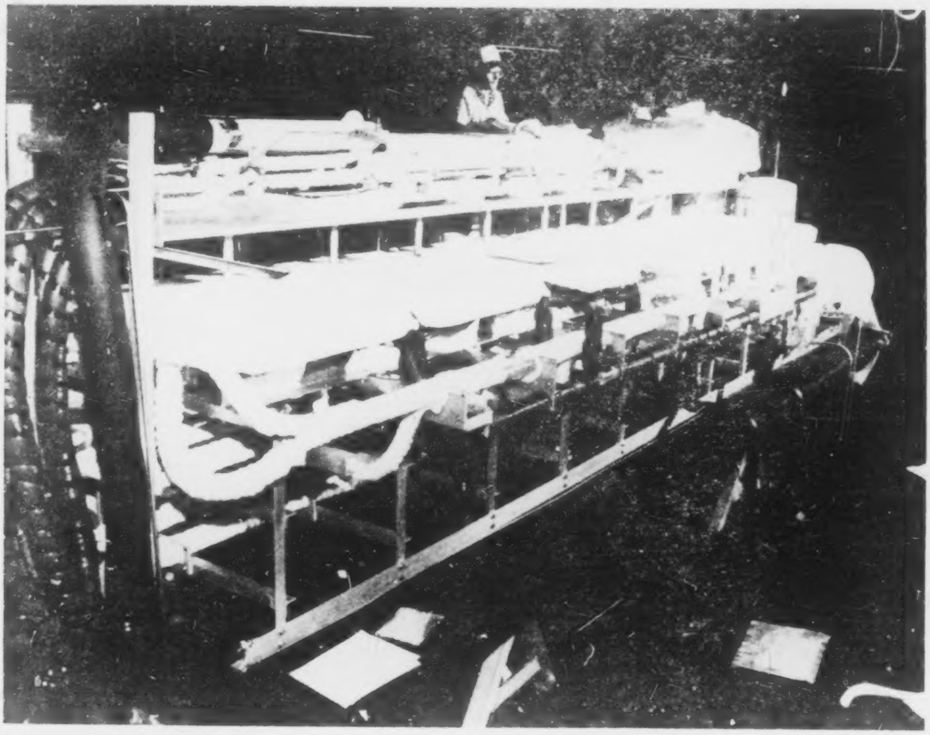


FIGURE 3.—Thermal management test bed illustrating folded, two-phase thermal loop at Johnson Space Center.

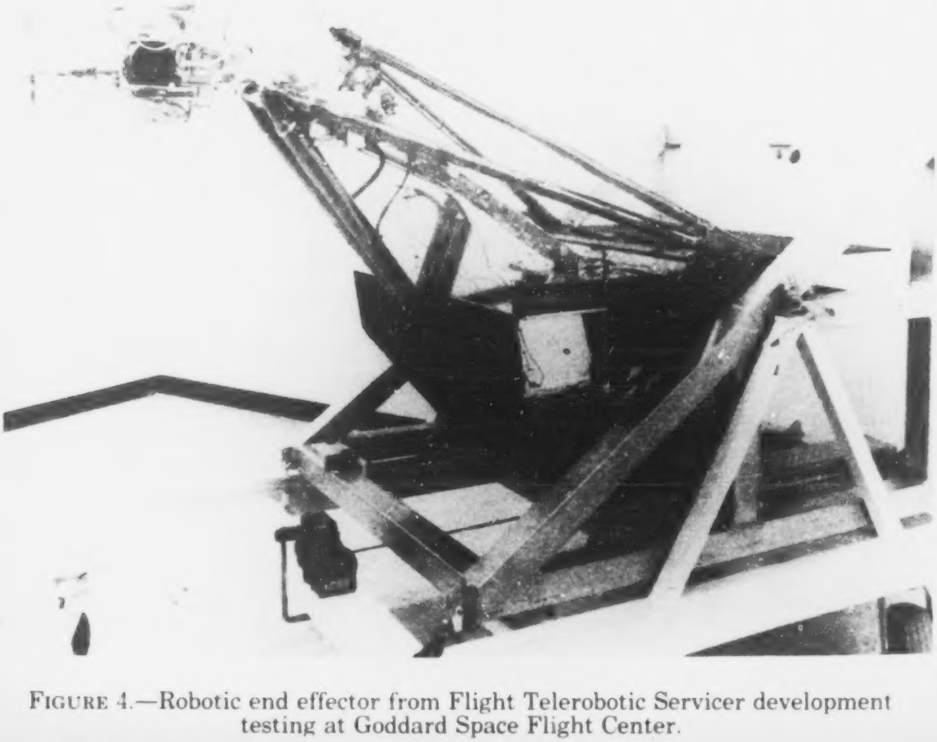


FIGURE 4.—Robotic end effector from Flight Telerobotic Servicer development testing at Goddard Space Flight Center.

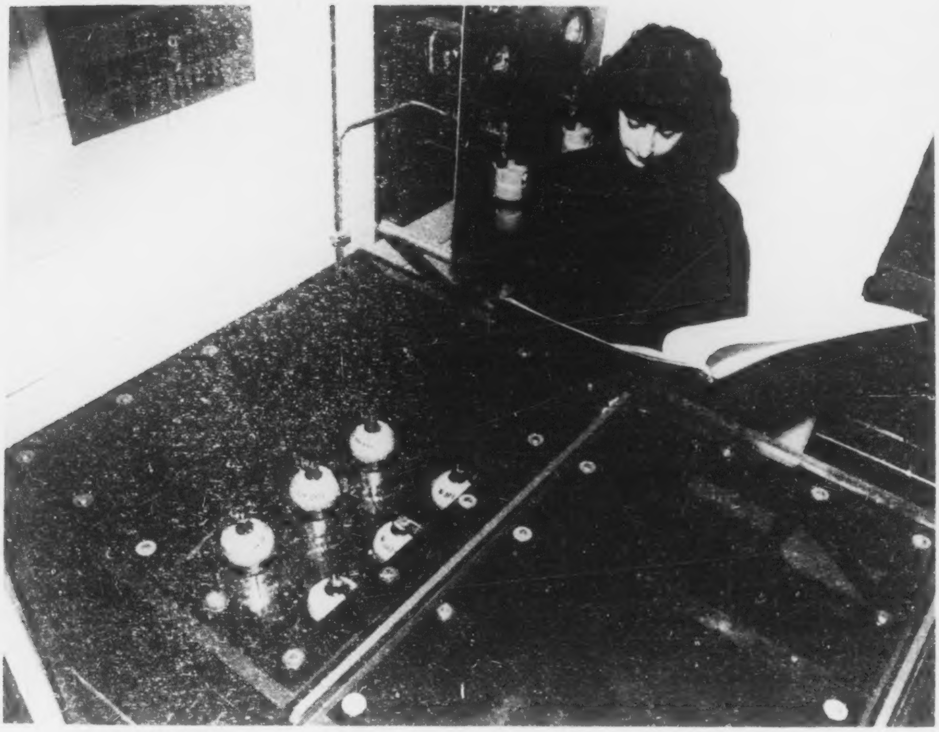
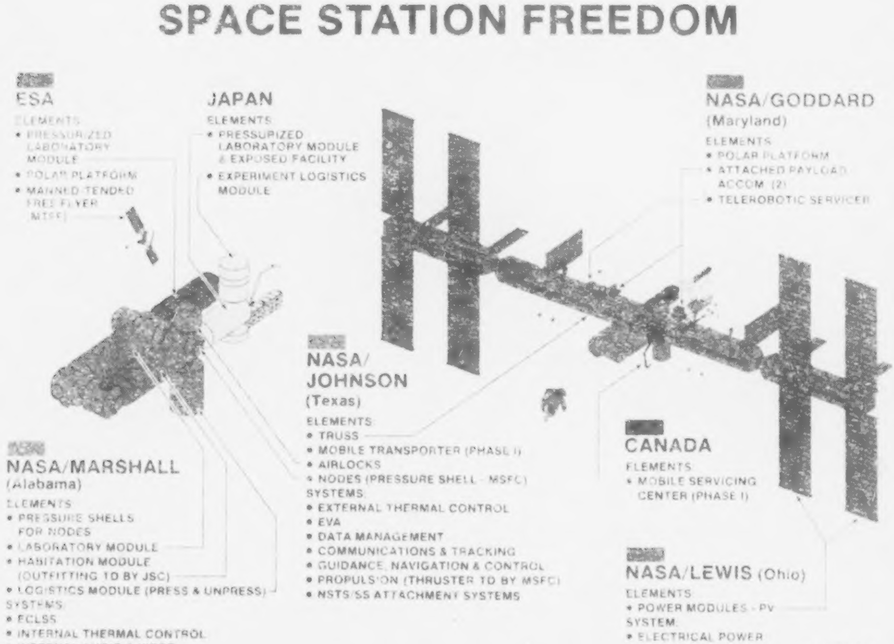
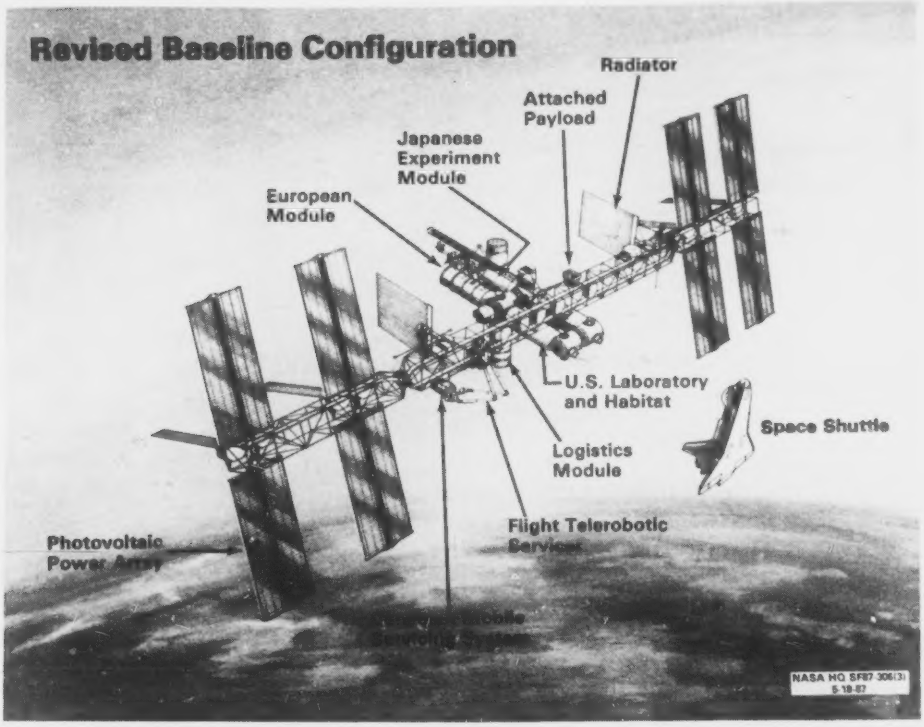


FIGURE 5.—Nickel-hydrogen battery cells in the Lewis Research Center Space Power Research Laboratory.


SPACE STATION FREEDOM
ESA
ELEMENTS
• PRESSURIZED LABORATORY MODULE
• POLAR PLATFORM
• MANNED-TENDED FREE FLYER (MTFF)
JAPAN
ELEMENTS
• PRESSURIZED LABORATORY MODULE & EXPOSED FACILITY
• EXPERIMENT LOGISTICS MODULE
NASA/GODDARD
(Maryland)
ELEMENTS
• POLAR PLATFORM
• ATTACHED PAYLOAD ACCOM. (2)
• TELEROBOTIC SERVICER
NASA/JOHNSON
(Texas)
ELEMENTS:
• TRUSS
• MOBILE TRANSPORTER (PHASE I)
• AIRLOCKS
• NODES (PRESSURE SHELL - MSFC)
SYSTEMS:
• EXTERNAL THERMAL CONTROL
• EVA
• DATA MANAGEMENT
• COMMUNICATIONS & TRACKING
• GUIDANCE, NAVIGATION & CONTROL
• PROPULSION (THRUSTER TD BY MSFC)
• NSTS/SS ATTACHMENT SYSTEMS
NASA/MARSHALL
(Alabama)
ELEMENTS:
• PRESSURE SHELLS FOR NODES
• LABORATORY MODULE
• HABITATION MODULE (OUTFITTING TD BY JSC)
• LOGISTICS MODULE (PRESS & UNPRESS)
SYSTEMS:
• ECLSS
• INTERNAL THERMAL CONTROL
• INTERNAL AUDIO & VIDEO
CANADA
ELEMENTS
• MOBILE SERVICING CENTER (PHASE I)
NASA/LEWIS (Ohio)
ELEMENTS
• POWER MODULES - PV
SYSTEM:
• ELECTRICAL POWER DISTRIBUTION
OSSTT 86E


Revised Baseline Configuration
Radiator
Attached Payload
Japanese Experiment Module
European Module
U.S. Laboratory and Habitat
Space Shuttle
Logistics Module
Flight Telerobotic Servicer
Photovoltaic Power Array
Mobile Servicing System
NASA HQ SF87-306(3) 5-18-87

Senator Robb. Thank you very much, Mr. Odom.

Mr. Tanner, if you are prepared, I think it might make sense to go ahead and make your presentation at this time. And we will pick up on any questioning when the chairman returns.

Mr. Tanner. Mr. Chairman, let me just address some brief remarks about the current organization at Reston, since that is the area I am primarily involved with on a day-to-day basis.

My presentation is relatively brief. I would like to second what Mr. Odom said, that we have in fact the right management program in place, and the right management structure. We are making substantial inroads and progress into getting the program organized and realizing the additional benefits of moving out right smartly, as we explained we would do last year.

I did not come with a prepared statement. I think that is the extent of the remarks I would like to make at this time, sir.

Senator Robb. The acting chairman has a parochial interest in some of your concerns, but we will wait.

I have just been handed a note that Mr. Anderson has no prepared testimony either. Mr. Anderson, would you like to make a statement?

Mr. Anderson. I would just like to observe that I think that the budget that we have submitted to you is a sound one and that we are well on the way to achieving the program within that budget.

Senator Robb. Thank you, Mr. Anderson.

Mr. Odom, you made reference to the fact that any delay might create some real difficulties. Can you give us some sense of the magnitude of that, without putting it in strict budgetary terms at this point? What kind of a delay would cause the program to have to be scrubbed altogether?

I remember in previous presentations that there was some concern that if we do not make the kind of commitment that is necessary to this project, that we ought to scrap it altogether. And I am not suggesting that you are advocating that by any stretch of the imagination. But as a practical matter, in a time of very serious budget constraints, could this be stretched out in any way shape or form without making it so inefficient and so costly that it becomes less feasible, say, as an alternative?

Mr. ODOM. Mr. Chairman, obviously one would have to qualify and quantify reductions, but let me just address your question. I think if you look at where the program has been, and where we are now, we are at an extremely crucial buildup of bringing the contractor teams that are on place and putting the muscle in those teams, putting the subcontractor teams together, and getting into the long-lead procurements and the long-pole testing.

So, I think to take virtually any cut from the numbers that we have submitted would be tantamount to basically doing major hurt to the program.

A significant cut below where we are, I think, would be tantamount to killing the program. And I think that to do that would almost be irresponsible on our part, especially looking at the commitments that our international partners have made and the investment that our contractors and we have made up to this point in time.

Also, during the initial design phase of a program that is as complex as this, not designing in adequate margins to accommodate life-cycle costs and operational costs would hurt the efficiency and increase the cost, not only of the development but also of the operation.

We are at a very crucial crossroads in this program. And it is almost imperative that we continue if we really want this space station program.

Senator ROBB. Could you comment on any slippage that might occur, in terms of its impact on any of our partners in this particular project?

Mr. ODOM. As a matter of fact, our partners have committed in excess of $8 billion in this year's dollars. And they have their plans, they have their teams up and going. For us to slip the program would essentially start to significantly increase their cost and increase I think their concern in continuing to support the program. It would begin to cause real concern on the part of our partners if we do not continue on the schedule that we have negotiated with them.

Senator ROBB. I have a couple of questions here that the chairman was planning to ask. I will ask them in his stead.

The first question has to do with cultural change and the primary differences between this space station program and prior NASA missions. How well suited is the NASA culture for developing 30-year facilities? And are you confident the systems engineering and systems integration activity, as a key challenge to this new type of project, are well defined and that the responsibilities are clearly assigned?

And has anybody ever integrated a project of this complexity?

Mr. ODOM. I think I will take questions in the reverse order. Relative to the complexity of this program, I do not think anyone has put together one that has hardware and systems coming from as many different suppliers and as many different countries. However, I do think that the hardware is certainly within our technologies, many of which have already been demonstrated. So, I think it is certainly reachable.

Relative to the culture, it is true that few systems have been built that have been asked to last 30 years and to operate for 30 years with minimum logistics and without the ability to either come back to dock, or to land, or to surface for air. It is a new culture for us to think in terms of that long an operation and the logistics and support that will go with that.

But I do not think that it is something that is beyond our reach. It will be a challenge, both engineering and management.

Growth from hooks and scars, will also be a challenge. But it is an engineering and management challenge, and one that I look forward to, because it is not something that is also outside of our reach. And I think the new technologies that we see on the horizon in the next five to 10 years can be accommodated in our initial designs.

Senator ROBB. The Reston Space Station Program Office is responsible for the complex management and technical issues of the space station program, including critical engineering and integration, software rules and tools, and the technical information system.

What is the current status of these activities and are the three support contractors working out? Grumman, I understand, is the program support contractor; Lockheed is software support environmental contractor; and Boeing is the technical and management information systems contractor.

Mr. TANNER. Yes, Mr. Chairman, let me take those in this order.

First the SSE environment, the activities that Lockheed is doing. We are in the process of installing the software that is produced by this contractor for different software production facilities. In the various NASA installations and installations of the prime contractors, the SSE software contract is relatively on schedule and is producing in the manner that we had hoped that it would.

The TMIS activity is very well advanced in the area of automating the business management and the translation of—or transportation, I should say, of documentation electronically, relative to reports, business activities like budgets and program controls and schedules.

We are just in the process of initiating the activity that will produce the hardware, related to computer-aided engineering and computer-aided manufacturing, which we hope to have on-line in the early part of next year.

The part that we do have in place works relatively well. It is like all large interconnected information systems. There are things that we are doing to it to make it work better.

Relative to the Grumman activity, the Grumman people are heavily integrated into the daily activity at Reston. We are addressing areas that will improve their capability as an integration contractor. And I am well satisfied with the activity that Grumman is doing.

Senator ROBB. Does the Reston office have the necessary civil servant integration engineers to oversee the development of this complex system?

Mr. TANNER. We, of course, have a very substantial number of those people on board. Our systems engineering and integration activity is staffed at a level of about 65 people, which needs to be increased by about 50 percent. We are actively hiring a number of those that are authorized by funds to fill those spaces. We do need additional authority to do that, and we have activity underway to do that.

We are somewhat understaffed in system, engineering and integration. We have plans, hopefully, by the middle of the year to be further up on that curve of getting staff to do that job.

Senator ROBB. What does it mean when you hear that NASA has baselined an integration program schedule, and what benefits result from this type of baseline?

Mr. TANNER. I think the central thing that it means is that we have proceeded to a point, considering all of the disparate elements that are involved in the program, to agree on an integrated schedule so that everyone is working to the same baseline, to the same sheet of music, if you will.

We all have the same milestones, guidance, points at which we must produce reports or definitive designs. It is just another way of saying that the program has gotten to the point where we can recognize the needs of the interdependent elements and everybody is working from this same reference baseline.

To say it is baselined, all it means is that everybody has to recognize that schedule and not one that they may have been previously working on up to an intermediate milestone.

Senator ROBB. Mr. Tanner, as I turn the gavel back over to our permanent Chairman, let me ask one more question before. I will relinquish the chair.

How have the associate contractor agreements facilitated preliminary design activities and how will they facilitate future integration activities?

Mr. TANNER. The associate contractor integration activity was and is a primary tool which now someone wants to use and intends to use to aid in the identification of the preponderance of hardware that has to be interchanged between not only the various NASA centers but the contractors that are contracted as prime contractors to those centers.

As Mr. Odom indicated a little bit earlier, this program is probably the most complex program that we have ever attempted, and that is one of the things that makes it so complicated is that there is a great number of hardware that must be delivered between the contracting partners and the NASA centers to enable the integration of the hardware into an end item that has to be flown.

The associate contractors are a prime element in identification down to the very small, minute piece part of this, what the schedule is that each of the contractors intends to deliver that piece of hardware to, and also the resolution of any technical problems that might be associated with that.

Today we, of course, are working in the very early part of the program as the ACA activity has proceeded very well to a definition of what that hardware is and what the framework is for working out the resolution of the problems. When the hardware actually begins to flow between all of the participating elements.

Senator GORE [presiding]. Thank you very much. Senator Robb, did you have further questions on this round?

Senator ROBB. No. As a matter of fact, Mr. Chairman, I was proceeding on a list of questions that had been prepared for you, so you are about two-thirds of the way through your questioning at this point.

Senator GORE. Well, I appreciate that. You have done a good bit of my work for me, thank you.

Senator Bryan, you are welcome to proceed if you have an opening statement, or just go right into your questions, either one.

Senator BRYAN. I will waive an opening statement and ask a couple of questions if I might. I would like to ask about our foreign partner participation in terms of the dollar amount and the program element that each may be responsible for.

Mr. ODOM. I will address that.

The contribution by our partners totaled approximately $8.3 billion. For ESA, or the European partners, it $4.8 billion, for Japan it is $2.5 billion, and for Canada it is roughly $1 billion, and so they are investing approximately $8.3 billion as compared to our roughly $16 in like year dollars.

Senator BRYAN. Now, is that contribution further broken down in terms of program responsibility for, say, the Japanese or the European space agency?

Mr. ODOM. We deal with it at the total amount just as you have implied within their own distribution of work within their countries, within the ESA, and within their own contracts, they do break it down much further, but we deal with them at the total level.

Senator BRYAN. This may be totally off the subject but insofar as any new technological breakthroughs occur by any of our foreign partners, a new threshold is crossed, a new area of sophistication embarked upon, who derives the benefit? Is that a shared benefit that each of the partners participate in or is there some national patent or other kinds of restrictions that would limit the ability to share that technology with us if, say, it was our partners who broke through?

Mr. ODOM. That is a very good question, Senator Bryan. It is the way this works, and we do have legislation that is in the works right now to deal with the patent rights and how those patents are processed. So, it would be a little bit premature for me to say exactly how that is going to work as that is literally being discussed between our attorneys and the Congress and the partners' attorneys. But that should come to fruition within the next month or so.

But, getting on to the individual experiments, the data that, say, that we derive in our own experiments, we do get access to that first and if we choose to share it, we can do it, but that it would be a choice that we would make on a case-by-case basis.

So, fundamentally each country that makes a discovery, he gets the first choice at that and it would only be shared as would be mutually agreed to subsequent to that.

Senator **Bryan**. I take it as implicit in your answer that we really have not worked the protocol in terms of—I guess it is a property interest really we are talking about in terms of American legal perspective.

Mr. **Odom**. That is correct.

Senator **Bryan**. Their laws are different than ours, and I suppose that creates at least some problems for us, but we really have not worked that protocol out.

Mr. **Odom**. Not totally. I think we are quite far along in that. Our intergovernmental agreements and our Memoranda of Understanding set the framework with which to do that. What we are discussing now are literally the details of the implementation.

Senator **Bryan**. If I could put just a little bit of spin on it, Mr. Odom, and to ask you if we have achieved an understanding in this area of our responsibility as one of the partners in the project.

Assume American scientists achieve a major breakthrough. That is subject to a patent process under American law. What is our obligation as a partner in terms of sharing in a property sense the benefit of that technological breakthrough from a potential commercial spin-off benefit?

Mr. **Odom**. From a commercial standpoint, obviously, we would want to retain that prerogative within our own boundaries. I think if it were a joint, truly a joint experiment, then obviously we would share it. If it is purely a unilateral experiment, then we would want to keep that in our own confines.

Senator **Bryan**. Mr. Chairman, thank you very much.

Senator **Gore**. Thank you very much.

Mr. Odom, last week this committee conducted a hearing on the proposed Mission to Planet Earth. The committee heard about an exciting proposal that has broad-based Congressional support as well as the support of the President.

A critical element of this proposed program is the Earth Observing System that will be deployed on the space station polar platform. Am I correct that the launch of the space station polar platforms will soon be delayed by another year from the fourth quarter of 1995 to the fourth quarter of 1996?

Mr. **Odom**. Mr. Chairman, as you indicated, the polar platform is that portion of the Earth Observing System program that is under the budget and the control of myself and this program. We are on a path to deliver it to fit the user requirement, and right now we would be on a path to continue that delivery in the fourth quarter of 1995. That obviously would be worked along with the experiments. Whatever the user dictates, we will support that.

Senator **Gore**. Well, let me see if I understand what you are saying. What you are really saying is that, yes, it will be delayed, but the delay is not your fault.

Mr. **Odom**. I am just saying that I do not think that the agency is to the point today to say that there is a delay for the hardware for which I am responsible. I see no reason why we will not be able to support the 1995 launch.

Senator **Gore**. There is no slippage in the availability of the polar platform?

Mr. **Odom**. Exactly.

Senator **Gore**. Are you aware of slippages in the availability of the earth observing system instruments?

Mr. **Odom**. I do understand that Dr. Fisk is working that. He now has made some selections, but I would not be knowledgeable of exactly where he is on that.

Senator **Gore**. If NASA were to take the lead of the Europeans and build a smaller expendable polar platform, would this situation be corrected?

Mr. **Odom**. I do not think the actual size to me is driving the schedule that much. Certainly not from a platform standpoint. We obviously respond to the user, and that would be more his call.

Senator **Gore**. Well, why is the U.S. building such a large complex polar platform and what is the status of the program review of whether or not the platform should be serviceable or expendable, large or small?

Mr. **Odom**. I think the size, you will find, will be driven by really the needs, the large complex of instruments that have been selected to fly on the platform, and the unification of those instruments and the data that will be coming from them. This should and will drive the size of the platform. Then we will respond to that.

Now, let me address the servicing. As you may recall, in the past, the program originally was to have launched the polar platform on the space shuttle from the western test range, in which case we would have had a servicing capability.

That is no longer the case. We are launching it now on a Titan, so we are now back reevaluating the necessity and desirability of servicing, and we will finish that study in the early to midsummer of this year.

Senator **Gore**. All right. Well, we are going to pursue some of this with Dr. Fisk, who will be coming in on April 11.

Now, on the budget cap issue, the President's fiscal year 1990 budget request includes language that would cap the Space Station Freedom development program at $13 billion in fiscal year 1984 dollars, adjusted for inflation and commercial participation.

Was imposition of this cap a NASA initiative or an OMB initiative and what is the basis for the estimate?

Mr. **Odom**. Mr. Chairman, that was a joint position, I think, by both NASA and OMB, for the implementation of the cap.

Contingent on our acceptance of a cap were basically two things, the total dollar value and the dollar profile per year that goes with that, $13 billion cap, and that is in 1984 dollars.

So, it was a joint agreement with OMB and with NASA, with those stipulations.

Senator **Gore**. Does NASA believe that the space station can be designed to cost and how would you react if the Congress handed you a check for $13 billion and said go build it?

Mr. **Odom**. The answer to that is—the first question is very definitely I think it can. And if Congress gave me $13 billion in 1984 dollars, I would be delighted to take that and go deliver it on schedule and as defined.

Senator GORE. You would not put it in c.d.'s?

Do you normally establish a cap for a program before or after the preliminary design review?

Mr. ODOM. We have many—there are not a lot of programs in our space transportation system that have been capped. Most of those are in our space science and applications office. And they have been both ways. We have capped some ahead of the PDR.

Senator GORE. Well, what specific items are included in the cap? What specific items are not included in the cap, and is funding for all of these items included in the proposed NASA space station budget runout?

Mr. ODOM. I will let Mr. Anderson address that?

Mr. ANDERSON. The cap addresses the development of the space station only, which is, of course, the four work packages plus the development of the infrastructure that is necessary to operate it and the support of the centers. But the space station development, $13 billion, that is covered by the cap.

Items not covered are the flight telerobotic servicer. We have some activity that is called transition definition which is to assure that the space station can evolve smoothly.

There are operations costs that are not covered in it. We are constructing a number of facilities that are not covered. The cost of the STS flights, the cost of TDRS support are not covered, and the civil servants supporting the space station are also not covered.

Senator GORE. The flights are not in the cap?

Mr. ANDERSON. Correct.

Senator GORE. What about the flight telerobotic servicer?

Mr. ODOM. It is not in that cap.

Senator GORE. What about the transition definition planning activities to ensure the space station design can add new capabilities and technologies to meet future mission requirements?

Mr. ODOM. That is not.

Senator GORE. What about the proposed orbital debris radar system?

Mr. ODOM. That is not, and that is a new item in our budget.

Senator GORE. What about the assured crew return capability or crew emergency rescue vehicle?

Mr. ODOM. That is not.

Senator GORE. What about the space station operations costs pursuant to the intergovernmental agreement?

Mr. ODOM. That is not.

Senator GORE. Senator Robb.

Senator ROBB. Thank you, Mr. Chairman. I have just one general question that relates to the concern, interdepartmental concern that we have experienced in our own government with regard to sharing technology, particular in joint U.S.-Japanese projects as highlighted most recently by the FSX proposal.

Is there a likelihood that we are going to have similar difficulties between NASA and Commerce and DoD and others that might be involved in terms of this type of an international venture and if so, are there any things that we can do to reduce the likelihood of those kinds of conflicts that would occur within our own government structure?

Mr. **Odom**. Senator Robb, that is a very excellent question. We have dealt with that, I think, starting back in 1984 and really worked that quite diligently with State Department, with Commerce, and with Congress as we built our Intergovernmental Agreements and we built our Memoranda of Understanding between ourselves and our counterparts.

I think we have excellent language in those agreements that will give us the adequate protection that we need. We fundamentally provide only the interface data. Where our partners' hardware interfaces with ours, and that is not a technology. And beyond that we have, I think, excellent control. I would not anticipate problems in that area.

Senator **Robb**. Thank you, Mr. Odom. Mr. Chairman, there are several concepts that I am going to have to get a little more basic briefing on before I am prepared to ask the kind of detailed questions that I think are appropriate at this time. I thank you.

Senator **Gore**. You and I will learn as we go along, because I am learning this also.

Senator Bryan.

Senator **Bryan**. No further questions at this time.

Senator **Gore**. Well, let me ask just a few more then on the cap, before we go on to our next panel.

Does the proposed cap of $13 billion assume the implementation of a life cycle costing methodology?

Mr. **Odom**. Very definitely. That is likewise a very good question because if there was ever a program that really demands a life cycle cost activity. We started that even in the phase B studies when we were really selecting the major subsystems—what type of subsystems we were going to install and utilize in the Space Station Freedom program. And so the answer is very definitely yes. That activity has already started, and we will finish up the details of the modeling and the partials that go into that this spring.

Senator **Gore**. Does the cap assume that the station will be metric or in U.S. units?

Mr. **Odom**. Right now it is in U.S. units. We are in the process of finishing up that study. I hope that I am within a month to six weeks of finishing that. Technically we have finished it. I need to understand the costs a little better, and then we will make the decision relative to it.

Senator **Gore**. Is there any cost effect from that decision?

Mr. **Odom**. Yes, there could be.

Senator **Gore**. How much?

Mr. **Odom**. I do not know, and that is what I am struggling with right now, to make sure that I understand that before I make that decision. We will plan to bring that back to the Congress probably within the next two months.

Senator **Gore**. Does the current space station planning activity assume the launch of the space station on the space shuttle with the redesigned rocket motor or the launch on the space shuttle with the advanced solid rocket motor?

Mr. **Odom**. Right now our baseline is the redesigned solid rocket motor.

Senator **Gore**. So, you are counting on that?

Mr. **Odom**. Right now we are not taking advantage of the performance capability that would come from the advanced solid rocket motor. That would be highly desirable for the space station program. And once the advanced solid rocket motor program is baselined and the performance is baselined, then we will take advantage of that.

Senator **Gore**. Well, at what point in the process will it be baselined?

Mr. **Odom**. Just as soon as that program is initiated, the contractor is selected, and the performance that should be expected from that is identified, then at that point—and we would hope that would be relatively soon.

Senator **Gore**. Well, do you see clear advantages to deploying the space station with an ASRM?

Mr. **Odom**. Absolutely. It provides us significantly more design margin, flight margin, and potentially less flights, so, it is a very highly desirable part of the agency's activities, and especially at the space station.

Senator **Gore**. Senator Lott and I feel that way also.

Senator **Lott**. A very good question.

Senator **Gore**. What advantages would there be to deployment of the space station on a Shuttle C, and are these being seriously assessed?

Mr. **Odom**. Yes. They are very definitely being seriously assessed. The real advantages are the flexibility that it would provide in the assembly sequence and also potentially less shuttle flights and also potentially less flights in total. So, it truly is an asset, and we have provided mission models to the Shuttle C people or mission manifests for them to exercise that design. Again that too would be a great advantage to our program.

Senator **Gore**. Now, what about the foreign partners? Are they required to pay the launch cost of the equipment that they provide?

Mr. **Odom**. Very definitely.

Senator **Gore**. And what about resupply and logistics transportation requirements?

Mr. **Odom**. The same there.

Senator **Gore**. All right. Now, are ESA and Japan designing their systems to be serviced by their own space transportation systems, either the man-rated Hermes for ESA or the H-II launch vehicle of Japan?

Mr. **Odom**. I believe the nature of the program is kind of that they are obviously designing their hardware to be deployed and taken up initially on the space shuttle. They are designing then their ELV systems to be compatible with that hardware. So, the answer is very definitely yes, they are looking at and I would expect them to use ELVs eventually in the logistic support of their hardware.

Senator **Gore**. Well, is that what you intend to do to service the space station, use ELVs?

Mr. **Odom**. We are looking at that likewise, and I think ultimately we will use ELVs.

Senator GORE. Have you given consideration to a man rated ELV in case the space shuttle were grounded?

Mr. ODOM. We have not because at this point we do not have obviously the man carrier to go on it. But that would be something that would have to come later.

Senator GORE. A couple of questions on staffing. Based upon the information provided to the subcommittee by NASA, the current number of NASA full-time equivalents or FTEs for the space station program is 1,851 compared to a requirement in the fiscal year 1989 budget request of 2,644 FTEs. The same requirement that exists in the fiscal year 1990 budget request.

What is the status of the fiscal year 1989 operating plan change to provide additional FTEs in fiscal year 1989 and how many additional FTEs would that change provide?

Mr. ANDERSON. The fiscal 1989 operating plan that we have submitted includes a transfer to $10 million from one fund source to another within the R&PM appropriation.

That $10 million is estimated to provide funding for an additional 200 civil servants throughout NASA. We estimate that we would get an additional 132 people of those 200 working on the space station.

Senator GORE. Are additional staff slots required in fiscal 1989 to keep the program on schedule?

Mr. ODOM. Absolutely.

Senator GORE. Will NASA request transfer authority in fiscal year 1989 to take care of the staffing situation?

Mr. ODOM. Yes, that is the plan.

Senator GORE. All right. What is the current estimate of the level of contractor support for the space station program and will that level increase dramatically with the release of the $515 million on May 15?

Mr. ODOM. Yes. That will increase dramatically starting in May, and I will let Mr. Anderson give you those numbers.

Mr. ANDERSON. Right now the prime contractors and their subcontractors are estimated to have something like 2,600 people on board. In addition, the centers have something like 1,200 support contractors supporting them, and we have a like number of contractors supporting the Reston activity.

Senator GORE. All right. Very good.

OPENING STATEMENT BY SENATOR LOTT

Senator LOTT. Mr. Chairman, I will be brief. I do not have any particular questions at this time.

I just want to apologize for missing your statement. I am looking forward to reviewing it.

I want to assure all of you that I am very supportive of the space station program. I am excited about the prospects.

It sounds to me like maybe we are beginning to turn the corner and move aggressively toward building the facility.

Even though in the past it has not had the funding it really needed, I think we are committed to seeing that it gets it, and I am going to be supportive of that effort in every way.

I look forward to hearing other witnesses this morning and hearing from you again in the future.

Mr. **Odom**. Thank you, Senator Lott.

Senator **Gore**. I believe we are ready to go on to the next panel but, Mr. Odom, before you leave, thank you very much for your very fine appearance here this morning. Mr. Tanner, Mr. Anderson, thank you all very much. We appreciate it.

Mr. **Odom**. Thank you, Mr Chairman, and for your support.

[The following information was subsequently received for the record:]

Responses to Written Questions Submitted by Chrm. Gore.

Space Station Budget Request

The FY 1990 budget request for NASA includes a three year funding request for the space station program of $2.050 billion in FY 1990, $2.980 billion in FY 1991, and $3.494 billion in FY 1992?

Question 1: If the FY 1990 request for the space station program is cut, will the program schedule automatically slip? Is this true for any reduction in FY 1990? What is the minimum level of funding that must be acquired in FY 1990 to stay on schedule?

Answer 1: Any significant cut to the FY 1990 budget request will result in a schedule slip. As both Dr. Fletcher and Mr. Odom have stated, there is no margin in our request -- $2.05 billion is the minimum required for the space station to stay on schedule.

Question 2: The FY 1990 budget request for NASA includes a three year funding request for the space station program of $2.050 billion in FY 1990, $2.980 billion in FY 1991, and $3.494 billion in FY 1992.

If the Congress does not provide a three year authorization and appropriation of $8.5 billion in FY 1990, will the schedule slip?

Answer 2: The request for a three-year authorization and appropriation is based on the need for stability in the funding for the Space Station. The stability offered by this approach enables meaningful implementation of the concurrently proposed legislation for a cap on the development costs. However, if the same funding profile is achieved through annual authorization and appropriations, there would be no impact on the development schedules.

Question 3: The FY 1990 budget request for NASA includes a three year funding request for the space station program of $2.050 billion in FY 1990, $2.980 billion in FY 1991, and $3.494 billion in FY 1992.

Am I correct when I assume that a slippage of one year in the schedule results in a cost penalty of $.5-$1 billion per year?

Answer 3: At this stage of the development program, a funding reduction that resulted in a one-year slip in the program would increase total development costs by approximately $1 billion in 1984 dollars.

Question 4: The FY 1990 budget request for NASA includes a three year funding request for the space station program of $2.050 billion in FY 1990, $2.980 billion in FY 1991, and $3.494 billion in FY 1992.

What is the effect of any further slippage in the program on the involved contractors and our foreign partners?

Answer 4: Additional slippage would cause the prime contractors and subcontractors to delay building up their workforce to the level required for the program. Moreover, since it is difficult to retain the best people in an unstable program, space station would lose good people at the prime contractors and subcontractors, and at NASA.

As for our foreign partners, a delay on our part would result in increased costs for them over which they have no control. Moreover, they would seriously question our commitment to the space station, and also question the reliability of the U.S. as a partner in this and other cooperative programs. The partners are all striving to maintain their strong financial and schedule commitments to the program, and they rightfully expect the U.S. to do the same.

Assembly Sequence

Question 5: What is the current assembly sequence for the space station, and have there been any changes to that sequence in FY 1989? Are any additional changes under review?

Answer 5: The reference assembly sequence has not changed in FY 1989, but we are now in the process of revising it to be consistent with current Space Shuttle payload requirements. The assembly sequence will continue to evolve as the space station design progresses, and we will continuously study potential alternatives to the reference assembly sequence as a normal part of engineering trade studies.

Question 6: Is an extended duration orbiter required for this assembly sequence? What about the orbital maneuvering vehicle?

Answer 6: The Extended Duration Orbiter capability will be employed for a science utilization/outfitting flight. Present planning does not require EDO capability, however, for specific assembly flights.

The OMV is not required for this assembly sequence. However, we are studying alternate sequences that make use of the OMV.

Question 7: What happens to the space-based hardware if during the assembly sequence the space shuttle is grounded for any reason? How long will the hardware stay on-orbit before its orbit decays?

Answer 7: The intermediate configurations of the space station are resilient to Shuttle downtimes for two reasons. First, each configuration will have some propulsion capability which will allow it to maintain orbit for up to 2 1/2 years. Second, the planned orbits are high enough that the hardware will stay up at least six months even without using reboost capability. The OMV provides some very attractive alternatives for problems such as this.

Question 8: Does the assembly sequence have room for any margin of error? If any hardware is lost, is the program totally jeopardized?

Answer 8: The assembly process will be fairly resilient for several reasons. Hardware will be capable of remaining on-orbit for extended periods. There is some redundancy of key functions, and malfunctioning components can be repaired or replaced in later Shuttle missions. Loss of hardware on a single mission would be a major setback, but it would not automatically jeopardize the program.

Crew Emergency Rescue Vehicle

It was recently reported that the NASA management had approved a Phase B definition activities for a crew emergency rescue vehicle for sick or endangered space station crew members.

Question 9: Did NASA management give approval to proceed with a Phase B definition on CERV and when will the RFP be released?

Answer 9: NASA plans to solicit proposals from industry to conduct a combined Phase A' (prime)/Phase B definition study of a Crew Emergency Return Vehicle. The Phase A' effort will focus on defining system requirements. Based on the results of the Phase A effort, the Office of Space Flight will establish validated system and mission requirements for the Phase B systems definition and preliminary design effort. In addition to the planned contracted effort, in-house efforts -- including support service manpower -- will be required to define a CERV operations concept. Release of the RFP is planned in June.

Question 10: Am I correct that there is only $7 million in the FY 1990 budget request to support these Phase B activities? Is that adequate?

Answer 10: The agency is requesting $7.0M for CERV in its FY 1990 budget, which combined with the $4.0M in FY 1988 and the $11.0M in FY 1989 will provide a total of $22.0M to complete the CERV Phase A/Phase B definition study requirements.

Question 11: And when does NASA anticipate a new start for such a vehicle in FY 1992?

Answer 11: Based on present schedules, NASA anticipates that CERV will be a candidate Phase C/D new start early in FY 1992.

Question 12: What is the current cost estimate of a CERV? Would that be in addition to the current NASA 5-year budget runout?

Answer 12: The current cost estimate for CERV is $1.4B - $2.0B in real year dollars. This estimate includes design, development, test, and evaluation costs plus costs for two sets of flight hardware. Assured Crew Return Capability (ACRC), which includes CERV as a candidate vehicle concept, is currently under agency consideration as an FY 1992 new start, but has not been formally adopted in the NASA's 5-year budget runout.

Orbital Debris Radar

The FY 1990 budget request contains a new space station initiative for an orbital debris radar system.

Question 13: Did the requirement for this new system emerge from the National Security Council's "Report on Orbital Debris" or from internal NASA studies?

Answer 13: Although the NSC report endorsed the need for more debris data and suggested that the Debris Environment Characterization Radar (DECR) could be used to obtain this data, the requirement for this new radar system was not the result of the NSC study report. The need for the radar has been established by internal NASA studies.

Question 14: What type of system will be developed and deployed? Where will this system be located, and when?

Answer 14: The desired performance can be provided by a radar system using either a single antenna for both transmit and receive functions, or two separate antennas for the two functions. In-house studies show that both types of systems are feasible, using currently available system elements. In other words, the desired performance can be achieved by putting together a system using commercial state-of-the-art equipment, without the need for a new R&D effort.

In order to get the maximum benefit of competition, the request for proposals did not specify a system; rather, it specified the desired performance, and left it up to the bidders to propose specific configurations. The final choice of a configuration will be made on the basis of performance, quality, schedule, cost and other factors, after reviewing the proposals received.

The system will be initially located in the continental U.S., either at the contractor facilities or at the Goldstone complex in California, in the spring of 1991 for test and preliminary data collection. In the fall of 1991 it will be moved to a location closer to the equator. This two-step approach is chosen to expedite the initial data collection: orbital debris data is needed in the summer of 1991 for the critical design review of pressurized elements of the Space Station Freedom. For long-term monitoring a location closer to the equator is desirable because debris from a larger number of orbits with various inclinations can be observed from there. Several sites (such as Ascension Island, Guam, Diego Garcia) are being considered for the final location. The possibility of turning over the long-term operations of the radar to the Department of Defense is also being explored.

Question 15: Am I correct that the feedback from this system (orbital debris radar) is a prerequisite for the critical design review (CDR) that is currently scheduled for the second quarter of 1992? What type of modifications to the space station design would the threat of orbital debris radar necessitate?

Answer 15: If the orbital debris radar shows that the debris threat exceeds current projections, the pressurized module designs must be modified to add increased protection. This can be accomplished by a change in shielding material, bumper spacing, or the provision of an additional shield on-orbit following initial assembly.

If it is known by CDR that additional protection is required, manufacture of the modules with the necessary modifications can begin on schedule. Failure to have this data by CDR will not preclude beginning manufacture, but program costs will be increased and schedule will be affected if modifications are later required.

Question 16: What is the total estimated cost of this system? And besides the Space Station Program, what other space activities would benefit from this type of system?

Answer 16: The Debris Environment Characterization Radar (DECR) is intended to measure and monitor, on a statistical basis, the small low earth orbit debris population down to 1 cm diameter. The schedule for DECR is driven by that of the Space Station Freedom, but the information on the debris population will be used by all designers and operators of satellites in low earth orbit. The need for accurate debris population estimates becomes more critical as the size of the satellite and the intended lifetime become larger. For example, space-based transfer vehicles which are large, long-lived and in low earth orbit would be susceptible to damage by orbital debris. The information collected by DECR could be used to determine whether or not shielding must be added to protect these valuable assets.

In addition, the DECR will be used to monitor the long-term evolution of the debris population. This will facilitate the identification and, hopefully, the elimination of sources of debris. Any reduction in the growth of the debris population would be beneficial to all users of space.

The total cost of the system is estimated to be $24 million from FY 1988 through FY 1991. This includes the cost of in-house studies and procurement activities during FY 1988 and FY 1989.

Space Station Power

I understand that as a result of recent decisions concerning . power distribution on the proposed space station that the current photovoltaic system only would provide 69 kilowatts of power instead of the design requirement of 75 kilowatts.

Question 17: Is this information correct, and what measures are being taken to correct this situation?

Answer 17: That information is based on the power generation capability of the electrical system at the end of its life on the worst power producing day of the year. The power requirement we are working to remains at 75 kW, so upcoming design decisions will ensure that this requirement is met.

Question 18: Will the design requirement of 75 kilowatts meet the projected "user requirements," or will it be necessary to initiate Phase II development of an additional 50 kilowatts of solar dynamic power?

Answer 18: The 75 kilowatts design requirement still appears to be a reasonable baseline. If the total power availability desired by the users exceeds the availability, a number of options will be considered. These range from increasing the output of the station's electrical power system to timesharing arrangements.

Question 19: What is the current estimate of the power requirements for "housekeeping" activities, as compared with "user requirements and experimentation?"

Answer 19: Since we are more than a year away from the preliminary design review, current housekeeping power estimates are only rough approximations. However, these early estimates indicated that the 30 kilowatts allocated could be exceeded. As a consequence, the designers were directed to come up with hardware designs requiring less power. Housekeeping power estimates will evolve as specific design decisions are incorporated into the preliminary design process.

Legislative Requirements

Mr. Odom, I recently introduced S.459, the Space Patent Bill, with most of my colleagues on the Committee as cosponsors.

Question 20: Is this the only legislative initiative that NASA needs enacted to implement the space station Intergovernmental Agreements?

Answer 20: Yes. This patent legislation is the only legislative initiative that needs to be enacted to enable the United States to enter the Intergovernmental Agreement into force.

Question 21: By what date is this legislation required?

Answer 21: The space patent legislation should be enacted as soon as possible, since it is required before the United States can ratify the Intergovernmental Agreement (IGA) that was signed with the international partners in September 1988. This important agreement cannot enter into force until it is ratified by the U.S. and one other partner.

Communications System

The space station program will rely on the Tracking and Data Relay Satellite System (TDRSS) for its communications and data management network. Based on recent reports, I understand that there is concern about the capacity of the TDRS system to handle the projected volume of data.

Question 22: Is there a concern about the TDRS System? Does that concern stem from the potential "user community" or NASA?

Answer 22: The NASA and potential "user community" concern about the TDRS system in the Space Station era is the number of on-orbit spacecraft required to provide the support projected by the Mission Model. Any delays in the STGT and/or TDRS replacement spacecraft represent a concern regarding the number of on-orbit operational TDRS's available to provide support for this mission set.

Question 23: Will our foreign partners also use the TDRS system to relay data to their ground stations?

Answer 23: The TDRS spacecraft will relay data only to the ground facilitie at White Sands, New Mexico. Foreign users of the TDRS system will receive their data at the White Sands ground complex or from another NASA data communication distribution gateway in the USA.

Question 24: What is the capacity of the current TDRS system, and are there any plans to augment that capacity with an Advanced TDRS System?

Answer 24: Each TDRS satellite can support two high data rate (300 MBPS) users simultaneously, in addition to supporting several low data rate users with the multiple access system. This 300 MBPS data handling capacity is sufficient for all individual users identified. However, the total quantity of these 300 MBPS links (single access antennas) is insufficient to meet the total requirements of the planned Mission Model, and it is this need which is dependent on both the STGT (to permit operating more than two TDRS simultaneously) and the replacement TDR spacecraft (to ensure TDR spacecraft are available as required.)

Implicit in NASA's reliance on a space tracking network is the need for follow-on spacecraft. An Advanced TDRS system, possibly with a capability to support future users with data rates of twice today's 300 MBPS, is under study.

Life Sciences

Based on my reading of the FY 1990 NASA budget request, it appears that NASA and OMB have finally come to recognize the importance of life sciences to extended manned space activities and to the space station program.

Question 25: Mr. Odom, will NASA now baseline a centrifuge in the space station facility?

Answer 25: A centrifuge is included.

Question 26: What additional life sciences initiatives will be intiated for the space station program?

Answer 26: NASA has been working toward two major life science activities for Space Station Freedom: the Space Biology Initiative (SBI) and the Extended Duration Crew Operation (EDCO) Program. SBI, for which we are seeking FY 1990 definition funds in preparation for a development start in the near future, focuses on the acquisition, development, and testing of the laboratory equipment that will be necessary to support basic life sciences research in space. This initiative is designed to provide verification of hardware in the Spacelab long module, wherever appropriate, prior to flight on the Space Station. The goal is to have in place, at the turn of the century, a state-of-the-art laboratory to be used by the United States (NASA and other Federal agencies) on the Space Station. SBI equipment will comprise capabilities for biological sample management and containment, physiological monitoring of crewmembers, plant growth, analysis of interplanetary dust particles, and, in addition, a centralized life sciences computer.

Under the SBI, we will continue the systematic investigation of a science question of universal importance: how gravity is sensed and how it it affects living systems. Other key SBI research topics include human physiology in space and closed-loop life support, which of the latter is intended both to help minimize costs for long-duration missions in the future, and to focus on questions of recycling materials in an ecosystem.

The goal of the EDCO Program is to complete the research necessary to medically certify Space Station Freedom crewmembers for tours of duty of up to 180 days, and thereby reduce requirements for crew rotation to five Shuttle flights per year. The United States has not yet obtained a comprehensive biomedical database on the effects of long-duration space flight on the human body. Through ground-based research and Shuttle experiments, the program will develop and assess the efficacy of countermeasures to weightlessness-induced changes in the body in order to protect the health of crewmembers both in space and after return to Earth's gravity field. Program objectives include the development of strategies to assure maximum productivity in space; verification of medical protocols, technologies, and procedures; and identification of the time interval necessary between missions, and the maximum number of repeat missions allowable for a crewmember.

Question 27: Mr. Odom, do you agree with the findings of the NASA Life Science Strategic Planning Study Committee report, "Exploring the Living Universe," that NASA's life sciences program must be expanded if one of our priorities is to place man in outer space under conditions that are safe and permit an adequate quality of life and work?

Answer 27: We certainly agree with the findings of the NASA Life Sciences Strategic Planning Study Committee that NASA's life sciences program must be expanded if we are to place humans in space under conditions that are safe and productive. We have little information on human interactions on space missions longer than routine Shuttle flights, as the United States has had no long-duration experience since the Skylab Program. During the Shuttle era, NASA focused its resources on short duration space missions which had a relatively small impact on astronaut health, but the issues become much more critical as we look toward the Space Station era. Assuring the health and safety of U.S. astronauts is important and, accordingly, NASA's FY 1990 budget reflects increased efforts toward the development of a strong program to ensure the health, well-being, and performance of humans in space.

Question 28: Why has the "life sciences" role and mission in the space station program been subjugated to materials processing and space science? Doesn't the success of the space station program and future missions depend upon the ability of man to function in space for extended periods of time?

Answer 28: The life sciences role of space station has not been subjugated to materials processing and space science. All three of these roles are important, and all three roles are being accommodated in plans for the space station.

Trial payload manifests for Freedom have identified many candidate life science payloads. Moreover, life sciences research requirements have directly affected space station design in several areas, including size and outfitting of the habitation module, and rack space availability for life science payloads.

Planning for life sciences research on Space Station Freedom has been an important part of the program since its inception, for it will enable us to acquire the knowledge about man's capabilities in the space environment essential to future human space exploration.

Senator GORE. I would like to call now Mr. John B. Winch, Director of the program management office of the space station at Boeing Aerospace in Huntsville, Mr. Robert S. Thompson, Vice President and General Manager of the Space Station Division of McDonnell Douglas Space Systems Company in Huntington Beach, California, and Dr. Lawrence Greenwood, General Manager for Spacecraft Operations of the Astro-Space Division at GE at Princeton, and Mr. George Hallinan, vice president for Space Station Power at Rocketdyne in Canoga Park, California.

Gentlemen, I would like to thank you and your respective companies for your willingness to participate in today's hearing on the space station program. I think we can all agree that we are at a critical juncture in this program and that a real commitment is required in fiscal year 1990 if this program is indeed going to be a reality. And we have got to urge an affirmative decision. Again, I am speaking as an advocate, but we are simply going to try to move the decision up to a point where it will be made and where it will be supported.

I am sure I speak for the entire subcommittee in saying that we are most interested in your comments today.

We thank you for being here.

We hope that as a result of your testimony we gain a greater appreciation for the way you see the space station and the way you rate the value of this program to the competitive posture of the U.S. industry in the marketplace of tomorrow.

Now, since NASA has been nice enough to give each of you a work package number, why do we not proceed in that order.

I believe that means you are up first, Mr. Winch, and then we will hear from Mr. Thompson, Dr. Greenwood, and Mr. Hallinan.

STATEMENT OF JOHN B. WINCH, DIRECTOR, PROGRAM MANAGEMENT OFFICE, SPACE STATION PROGRAM, BOEING AEROSPACE, HUNTSVILLE, AL

Mr. WINCH. Thank you, Mr. Chairman. I have submitted a full statement for the record, and I will give a summary at this point in time.

Senator GORE. That would be fine.

Mr. WINCH. I appreciate being given the opportunity to appear before this subcommittee to speak in support of the Space Station Freedom program and express the Boeing Company's commitment.

America needs Space Station Freedom. America leads in some of today's most important technologies because of space research conducted 10, 15, and even 20 years ago. That early research helped secure our nation's place in the world, improved our standard of living, and helped support our economy.

It is investment of this type that has established our American technological preeminence. Continued investment in such projects as Space Station Freedom promise long-term continuing payback in effective materials processes and potential industries will help ensure America's future as a leader in world markets.

Boeing's commitment to space is long standing. Our commitment to Space Station Freedom is a top corporate priority. Since 1984 we have invested more than $100 million of Boeing money in space station-related activities and facilities and are also committed to future investments in excess of $70 million.

While there are many long-range benefits to be realized from Space Station Freedom, I would like to home in on the benefits to be accrued from establishing a national laboratory in space. By placing permanent and well-equipped laboratory facilities in orbit, we will be able to conduct research in life sciences and materials and processes to a degree not yet experienced.

It is worthy of note that the Soviet Union's MIR space station module which has been in orbit since 1986 has been used to perform numerous materials processing experiments.

The Center of Macromolecular Crystallography at the University of Alabama in Birmingham specializes in space-grown crystals of biological materials that are identified by participating firms in pharmaceutical, biotechnology and chemical industries.

UAB has flown protein crystal growth experiments on five shuttle missions. And I would comment parenthetically that there is one in flight right now, an additional one.

The most recent flight, the STS-26 mission of Discovery, provided perfect crystals of canavalin, interferon and porcine elastase. These materials have each been the subject of intense investigation in the pharmaceutical industries because understanding their detailed structure will allow major biomedical advances.

Equally important to answer is, "Why perform materials and processes research in microgravity?" The history of industrial development is significantly a history of materials technology. Our ability to devise new inventions depends upon our ability to create materials with enabling properties.

Another near term use for the space station is as an earth observatory. But interacting physical, chemical and biological processes connect the oceans, continents, atmosphere and biosphere of earth in the complex way that affects our weather and ultimately the crops American farmers can yield.

A better understanding of the atmosphere and weather conditions could lead to improved weather forecasting and as a result agricultural breakthroughs.

We are deeply involved in the preliminary design phase of the program at this time and on our way to a preliminary design review in mid-1990. Significant progress has been made on program implementation.

A full scale mock-up of the pressurized elements is located in Marshall Space Flight Center facilities in Huntsville, Alabama. Reviews of this mock-up have been conducted by astronauts and incremental revisions will be incorporated as the design matures.

Prototype models of the environmental control and life support hardware will be delivered in midyear to support early confirmation of this key subsystem. A full scale model of the laboratory and habitat structure has been fabricated to demonstrate manufacturing techniques, and extensive studies have been conducted of other subsystems. To continue this process, our full subcontractor complement needs to be funded to support the design effort.

Americans have always felt that they should work hard and sacrifice to give their children a better life. Today it is more important than ever to extend a hand to the next generation, to help our kids succeed in a tough competitive world. We must increase America's rate of discovery and invention. That is what America's Space Station Freedom is all about, increasing American invention, discovery and supporting development of our technological base.

At Boeing we feel the Space Station Freedom program is ready to move forward at the pace required to meet these scheduled commitments. The requirements are in place and configuration definition has stabilized acceptably. The benefits to man, the legacy for the next generation, our children, and the boost to our continued leadership in space all justify the investment. Thank you.

[The statement follows:]

STATEMENT OF JOHN B. WINCH, DEPUTY PROGRAM MANAGER, SPACE STATION FREEDOM PROGRAM BOEING AEROSPACE, HUNTSVILLE, ALABAMA

Mr. Chairman, I appreciate being given the opportunity to appear before this Subcommittee to speak in support of the Space Station Freedom Program and express The Boeing Company's commitment. America needs Space Station Freedom!

Space Station Freedom will be an international laboratory in space to speed the American, and world, process of invention and discovery, leading to improved quality of life on Earth. Just as the United States' wind tunnel facilities have contributed to our world leadership in commercial aviation, so will Space Station Freedom ensure our competitive edge in space and advance a host of related "spin-off" technologies in ways impossible to predict. It will serve as a unique laboratory providing a peaceful, space-based center to conduct scientific research routinely in a nearly weightless microgravity environment; a scientific observation platform to discover new information about our planet Earth and its environment; a center for on-orbit satellite servicing and repair; and a permanent space base for the longer space voyages of the future.

America leads in some of today's most important technologies because of space research conducted 10, 15, and even 20 years ago. That early research helped secure our nation's place in the world, improved our standard of living, and helped support our economy. Millions of today's jobs exist because of yesterday's research. In part, this situation is the result of two things: the ingenuity and inventive spirit of the American people, and the investment and foresight of America's elected leaders. Our continued technological leadership in the global arena depends in great part on the funding decisions to be made this year about the space program, and more specifically, Space Station Freedom. American government has traditionally sown the seeds of technological advancement because history has shown that the expense of initiating such work is more than any single company or industry can muster. The results of those seeds have paid wonderful dividends through new industries including aerospace, aircraft, electronics, computing, and communication technologies to name only a few. These industries have touched each one of us. It is investment of this type that has established our American technological preeminence. Continued investment in such projects as Space Station Freedom that promise long-term, continuing payback in effective materials, processes, and potential industries will help ensure America's future as a leader in world markets.

Boeing's commitment to space is long-standing. Our commitment to Space Station Freedom is a top corporate priority. Since 1984 we have invested more than $100M of Boeing money in Space Station related activities and facilities and are also committed to future investments in excess of $70M. We competed for and won not only the Work Package 01 (WP01) Phase B contract but also more than 20 directly related Advanced Development contracts. We successfully won the WP01 Phase C/D competition, have been through the requirements revalidation period, and have initiated preliminary design. We have successfully completed the first major milestone, the Program Requirements Review, have initiated engineering design studies, conducted neutral buoyancy tests, and participated in crew station reviews. We are headed for our next major review, the Preliminary Design Review, in mid-year 1990.

Our WP01 responsibilities include developing and producing the U.S. provided pressurized modules in which the station's crew will live and work. This includes the astronaut's living quarters, known as the habitation module; the U.S. laboratory module; logistics modules used for resupply and storage; node structures connecting the modules; and distributed systems responsibility for the environmental control and life support system, the thermal control system in the modules, the internal audio and video systems, and man-systems equipment to promote comfortable living conditions and improved crew productivity.

Boeing has gathered an outstanding, experienced team for this effort. It includes Teledyne Brown Engineering of Huntsville; Lockheed Missiles and Space Company of Sunnyvale, California; and Grumman in Houston, Texas. Many other subcontractors representing the top technical companies in the U.S. have been competitively selected to develop the critical subsystems. As is typical for a project such as this, more than half of the funds we receive from NASA will be spent by our subcontractors.

I would like to make a very critical point here about our subcontractor effort: During the highly constrained 1988 and 1989 funding period, our subcontractors have been confined to supporting our requirements definition activities in a limited role. Now that we are into the preliminary design phase, a significant funding increase to the subcontractors is necessary to allow their critical involvement in the design and development process. FY90 budget deliberations must take note of this fact.

The Boeing Company is also responsible for designing and implementing the Technical Management Information System (TMIS) for NASA. TMIS provides a tool that supports efficient management and access to information necessary for the construction and operation of the Space Station. TMIS will assist in the preparation, organization, integration, and effective use of the vast amounts of technical and management data that are required in a program of the Space Station's magnitude. This system allows NASA and its contractors a timely exchange of management and design information throughout the life of the program. In short, TMIS is a management tool that provides visibility of cost and schedule control on the Space Station program.

While there are many long-range benefits to be realized from Space Station Freedom, I would like to home in on the benefits to be accrued from establishing a national laboratory in space. By placing permanent and well-equipped laboratory facilities in orbit, we will be able to conduct research in life sciences and materials and processes to a degree not yet experienced. It is worthy of note that the Soviet Union's Mir space station core module, which has been in orbit since 1986, has been used to perform numerous materials processing experiments.

Life sciences and space medicine research have already greatly benefitted medical science through better understanding of biological processes, and especially through technology advancements that facilitated many new noninvasive diagnostic and imaging techniques. An outstanding example of technical contributions to date is in the area of protein crystal growth.

The Center of Macromolecular Crystallography at the University of Alabama in Birmingham (UAB) specializes in space-grown crystals of biological materials that are identified by participating firms in pharmaceutical, biotechnology, and chemical industries. UAB has flown protein crystal growth experiments on five Shuttle missions. The most recent flight, the STS-26 mission of Discovery, provided perfect crystals of canavalin, interferon, and porcine elastase. These materials have each been the subject of intense investigation in the pharmaceutical industries because understanding their detailed structure would allow major biomedical advances. Canavalin is important as a food substance and research may lead to the ability to genetically engineer more nutritious food. Gamma interferon is a protein in our immune system that is part of the cascade of immune events in our system, and research may lead to therapies for auto-immune diseases and transplant rejection. Porcine elastase is being investigated for possible drug design efforts for emphysema. The presence of a permanent human research facility will teach us more about the human body. It will have applications both here on Earth leading to more effective pharmaceuticals and medical procedures, as well as information on how humans, animals, and plants adapt in our quest to explore the Solar System.

Equally important to answer is, "Why perform materials and processes research in microgravity?" The history of industrial development is significantly a history of materials technology. Our ability to devise new inventions depends upon our ability to create materials with enabling properties. Witness the dependence of aerospace vehicles on high-strength, lightweight structural materials and the emergence of an entire, huge industry built on the special properties of semiconductors.

In Space Station laboratories, scientists will be able to perform experiments involving processing ordinary and comparatively low-value raw materials into crystals, chemicals, metals, ceramics, and other manufactured products. The unique environment in space allows materials to interact in ways impossible with the gravitational pull on Earth. On Earth, gravity causes materials of different densities and temperatures to separate and materials to deform under their own weight. In microgravity, these unwanted effects can be avoided. The result is improved physical structure of materials when melted and solidified and large increases in purity. For example, crystals grow larger with fewer imperfections in microgravity.

Presently the rate of advancement in materials processing in space is extremely limited by the lack of routine access to the microgravity environment. Flight opportunities are infrequent and short. Other means such as drop towers, aircraft, and sounding rockets are severely limited in exposure time, quality of the microgravity environment, and experiment volumes. NASA, the research community and industry are beginning to increase the inventory of useful materials processing equipment by developing crystal growth facilities, containerless processing facilities, furnaces for metals and alloys processing, and electrokinetic separation equipment. The presence of the crewman to interact with the experiments directly to gather data and products and recycle experiments greatly accelerates the process development flow time.

The Space Station laboratory facilities will provide adequate lab space, power, crew time, equipment, and operating flexibility to capitalize on these developments and significantly shorten the research and development time to perfect new materials and processes. Experiments are planned in such areas as fundamental fluid dynamics and transport phenomena; combustion sciences; basic heat and mass transport phenomena in fluid media; containerless processing; crystal growth by a number of processes, including vapor transport, supersaturation and cooling, directional solidification, and float-zone refining; formation of metallic alloys; critical-point phenomena; and cloud-formation microphysics. These research areas require, as does all empirical science, accumulation of statistically significant data that can only be generated by a large number of experimental runs. Space Station offers the first opportunity to remain on orbit long enough to perform this kind of investigative research. Results obtained in orbit will be useful both as a precursor to subsequent production of materials on orbit and to improved production on Earth. Knowledge of gravitational effects can be valuable in improving Earth-based manufacturing and processing.

Another near-term use for the Space Station is as an Earth observatory. Today, we are limited in the ability to foresee changes in the Earth system and the subsequent effects on the planet's physical and economic climate. Global-scale changes of uncertain impact, ranging from an increase in atmospheric warming gases to important variations of vegetation covers in coastlines have already been observed with existing measurement capabilities. But interactive physical, chemical, and biological processes connect the oceans, continents, atmosphere, and biosphere of Earth in a complex way that affects our weather, and ultimately the crops American farmers can yield. A better understanding of the atmosphere and weather conditions could lead to improved weather forecasting and, as a result, agricultural breakthroughs. A better understanding of such weather systems as hurricanes and their impact on the environment, can help us predict--and react to--them effectively.

We are deeply involved in the preliminary design phase of the program at this time and are on our way to a preliminary design review in mid-1990. Significant progress has been made on program implementation. A full-scale mockup of the pressurized elements (pictured in the attachment) is located in Marshall Space Flight Center facilities in Huntsville, Alabama. Reviews of this mockup have been conducted by astronauts; incremental revisions will be incorporated as the design matures. Prototype models of the environmental control and life support hardware will be delivered in mid-year to support early confirmation of this key subsystem. A full-scale model of the laboratory/habitat structure has been fabricated to demonstrate manufacturing techniques and extensive studies have been conducted of the other subsystems. To continue this progress, our full subcontractor complement needs to be funded to support the design effort.

Boeing is a major supporter of the commercialization of business opportunities evolving from the U.S. space program. We formed the Boeing Commercial Space Development Company to exploit these opportunities and presently have a proposal under review by NASA to utilize the Space Station logistics module for commercial purposes. We have invested in the development of an electro-optical materials furnace and other commercialization opportunities. We believe that additional opportunities for private enterprise will be stimulated and developed by the operation of Space Station Freedom.

Americans have always felt they should work hard and sacrifice to give their children a better life. Today it's more important than ever to extend a hand to the next generation. To help our kids succeed in a tough, competitive world, we must increase America's rate of discovery and invention. Space is one topic that has played a key role in American classrooms over the last three decades. The studies have excited the imaginations of these next generations of explorers--in fact, thousands of kids sign-up for the rigorous Space Camp programs each year at the Space and Rocket Center in Huntsville, Alabama, rather than spend their summers at a more traditional camp--and in this way the seeds are planted for our future scientists, researchers, engineers, and mathematicians. That is what America's Space Station Freedom is all about: increasing American invention, discovery, and supporting the development of our future technological base.

At Boeing we feel the Space Station Freedom program is ready to move forward at the pace required to meet the schedule commitments, the requirements are in place and configuration definition has stabilized acceptably. The benefits to man, the legacy for the next generation--our children, and the boost to our continued leadership in space all justify the investment.

Senator GORE. We are going to hear all of the witnesses before questions if that is all right.

Mr. Robert Thompson is Vice President and General Manager with the Space Station Division of McDonnell Douglas. Please proceed.

STATEMENT OF ROBERT F. THOMPSON, VICE PRESIDENT AND GENERAL MANAGER, SPACE STATION DIVISION, McDONNELL DOUGLAS SPACE SYSTEMS CO

Mr. THOMPSON. Thank you, Mr. Chairman, members of the subcommittee. I would also like to submit a written response to your kind letter of invitation where we have tried to respond specifically to each point you asked us to comment on in the letter.

I would like to confine my verbal remarks here this morning to just two general areas that were encompassed in the information you asked us to respond to in the request for our views of the President's budget request for the next three years, FY 1990–1992.

I think to paraphrase one question, one of the subjects that you were leading to is "are we really ready to turn on this level of funding and utilize it efficiently and effectively." I would like to comment on that one, and then I would like to come back and talk to the general thrust of your request relative to our perceived benefits of the space station, both from a company perspective and from a national perspective.

Let me first comment on are we ready to utilize the money effectively, and I am going to remark primarily from work package 2, which is where I spend my time.

I am the industry project manager for that particular work package and to put that work package into perspective we are under contract to the Johnson Space Center in Houston to deliver several critical flight elements, and we call elements those pieces of hardware that you can see and touch for example a resource node or an air lock or the large central truss structure, the propulsion subsystems and items of that nature, and then we are also under contract to deliver five critical distributed systems. These are systems that not only are located in the elements that we deliver, but also on the elements that some of my colleagues deliver.

And likewise as you have heard we receive some hardware delivered from our associate contractors and we work together to make sure that we integrate across the space station the proper systems that make the elements play together as an identity.

Now we have had the capability for about 30 years to fly into near earth orbit with people. The first ten years of that activity was spent primarily in understanding what the initial reaction of man to earth orbital flight would be in developing some rendezvous and maneuvering flight capabilities, and then we embarked upon a lunar exploration activity. That pretty well carried us through the first ten years.

For the last 20 years we have been focusing on developing, as far as manned spaceflight is concerned, an earth orbital infrastructure and, frankly, when we made this basic decision in 1969 to shift our effort back toward the earth orbital infrastructure and build a shuttle and a space station, we probably thought at that time in something like ten or 15 years we would have it accomplished.

We are now in excess of 20 years from that decision time period, and it is going to be more like 25 to 28 years by the time we accomplish the shuttle/space station fundamental part of the infrastructure.

The last several years, starting heavily in 1982 and then very intensely in 1984, an extremely meticulous job has been done in reviewing the requirements for a space station, in reviewing the architecture for the space station and by the word architecture I am talking about the general plan of how we would build the station and the versatility that we would achieve out of this plan, is it something that the nation can operate effectively for 25 to 30 years and perform the research, operations, and development activities that we think are important in this near earth orbit environment.

I think an extremely good job has been done in reviewing the needs and potential benefits, in developing the basic architectural approach to get the versatility we need, and I think we are in an excellent position, certainly, from those elements and in those distributed systems that we have a responsibility for to now turn on the buildup of effort.

It is characteristic of development programs of this nature that you can study things for a period of time with relatively lower levels of funding, but once you reach a certain point, you can only talk effectively about things so long. You then have to start building the hardware and you have to start bringing subcontractors and vendors on board.

You have to get the test articles in the vacuum chambers, you have to get the electronics into breadboard development, you have to get the mock-ups made so that you can walk through them with your crew station reviews and activities of that nature. And, we are very much in that readiness posture today.

In fact, the way the fiscal year 1989 funding has been released by the government, it is certainly causing us at work package 2 to hold back through the 15th of May. There are a number of things we could be doing today that would be very constructive to getting on with meeting this calendar year 1995 first element launch and the 1996 permanent manned configuration that we could be moving very effectively on today if that funding were available.

So, we are definitely in a position where we can accommodate the funding buildup certainly for that part of the budget that has been identified to you relative to work package 2, and it would be my judgment, based on observing other elements of the program, that similar needs exist there also.

I think overall the budget request is a very sound request, and I think the country has spent ample time preparing for a space station. I think now is the time to go implement the space station.

I think also our international agreements are in an excellent position to move on with it. So, I am very confident that the resources if made available will be spent very effectively.

I could take more of your time and probably list 50 different individual uses of funds that are just in front of us, everything from various design and mock-ups activities, to breadboard electronics to test activities and water tanks evaluations. We are there, ready to go, and I can assure you the funding will be used effectively.

Secondly, as far as the schedule of funding for the three years and the general benefits of space station to our society, again, I could probably talk for the rest of the morning. I will have to try to figure out what to say here in a matter of a couple of minutes.

Typically on development programs of this nature once you turn on the true hardware development, building and implementing phase, you have to bring a fairly large body of people on board. Once you get those people on board, you want to move rapidly to utilize the people effectively because people are money. And so you then need to sustain the funding so that you can perform the development activity in a period of three or four years.

If you flatten out the top of that curve and drag it out for longer periods of time, you bring certain inefficiencies into the program and then when you integrate under that total curve, it ultimately costs you more money in the long run, and it takes you longer to get in place this research and development laboratory that I think is going to be very beneficial to all of us.

So, I think it is very important to get your ducks in a row. Once you start, you ought to be willing to sustain it and get over the development hump in something like the three-year funding that is in front of us.

So, I would certainly endorse the type of budget profile that has been submitted to you here today. The benefits to our society as a spacefaring nation for the space station, there have been thousands of pages written on that. I think, again, it is too simplistic to ask for any one or two specific reasons why we as a nation need a space station.

I spent the first ten or 15 years of my working career at an aeronautical research laboratory back in the late forties and early fifties. If you had asked those of us doing research work at that time if we really understood the blossoming of world transportation that was just ahead in the aeronautical field and the tremendous cost benefits to our nation of being a leader in transportation of that nature, I doubt if those of us in the research center could have given you the answers that history subsequently brought forward.

I think a similar situation will be true in the space station. I think as a society it would be a shame if we did not move on now. We have been talking about this for 20 years. I think it is about time to go do it. So, as a taxpayer, I have no trouble at all endorsing the need for a space station if we truly intend to be a spacefaring nation, and I really think we truly intend to be that. Thank you very much.

[The statement follows:]

STATEMENT OF ROBERT F. THOMPSON, VICE PRESIDENT AND GENERAL MANAGER, SPACE STATION DIVISION, MCDONNELL DOUGLAS SPACE SYSTEMS COMPANY

Mr. Chairman and Members of the Subcommittee:

I am pleased to have this opportunity to discuss with your Subcommittee McDonnell Douglas' contribution and involvement in NASA's Space Station Freedom program. I would like to give you our program status, our needs and requirements, our anticipated schedule and budget profile, and the benefits of the Space Station program.

Program Status

McDonnell Douglas is the prime contractor for Work Package 2, administered by the Johnson Space Center in Houston. Within this work package, we are responsible for the design, development, test and evaluation (DDT&E) of several flight elements - - the integrated truss assembly, the airlocks, outfitting of the resource nodes, the mobile transporter, propulsion, the docking system for the Shuttle and several distributed systems - - data management, communication and tracking, guidance, navigation and control, thermal systems, extra-vehicular activity (EVA), assembly and external maintenance. Our four major subcontractors are Honeywell, IBM, Lockheed, and General Electric.

The Space Station Freedom program is firmly in place and on schedule to launch the first element in the first quarter of CY 1995 with a permanent manned presence in space achievable during the fourth quarter of CY 1996. We all participated with NASA in definition studies over the last five years and have developed a versatile space station configuration - - reviewed and endorsed by the National Research Council - - that accommodates both current and future users. Once the definition was complete, NASA awarded the four Work Package contracts in December 1987. After the award of our contract, we moved to the next major program "milestone" - - the program requirements review. This activity - - completed in October 1988 - - formally defined the Space Station critical system and element design requirements and laid the groundwork for McDonnell Douglas to begin the preliminary design activities for our work package. This preliminary design review (PDR) phase is scheduled for completion in the summer of 1990.

Needs and Requirements

It is imperative to maintain the funding profile proposed by the Administration in order to accomplish these critical tasks, to integrate components in a timely manner, and to remain on schedule. Any degradation of this proposed funding will undoubtedly result in inefficient and costly reprogramming. Our contracts have been signed with our subcontractors. There is a certain "trickle down" effect that takes place in adjusting funding availability for a large contract award such as this. Because of past inconsistencies of funding, there have been interruptions of funding to our subcontractors and to their subcontractors. We are now making a concerted effort to target these funds to be sure that critical items are completed on time for integration into the overall project. Any further delays or interruptions in this funding trend will undoubtedly force serious reprogramming and possible delay of the program.

The funding limitations for the first 7 1/2 months of FY 1989, as specified in the appropriations bill, have already restricted certain activities and have required replanning to avoid falling out of step. The current Work Package 2 team includes about 1200 persons. Because of the restrained spending in the first half of this year, we have begun the process to expand the team capabilities quickly when additional funds are released May 15 in order to maintain the program momentum for a First Element Launch in the first quarter of CY 1995.

McDonnell Douglas has worked on a Space Station concept and program for more than twenty years. Our company believes that a Space Station should be a "given" in our Nation's space infrastructure. We as a Nation cannot afford to fall behind as the spacefaring leader. Because we believe that the United States benefits and, consequently, our industry will benefit from this investment in our future, our team had invested nearly $200 million in this project up through the contract awards at the end of 1987. This was done with no assurance that we would be allowed to participate. We saw this program as a great future for our companies and for our country.

Schedule and Budget Profile

Our own work package schedule and budget profile are based on this year's funding of approximately $200 million to Work Package 2 and a target of a first element launch in the first quarter of CY 1995. To meet that objective, a funding increase to about $500 million in our contract is needed in FY 1990. We have done extensive planning to assure the most efficient application of that funding, both internally and with our major subcontractors. We anticipate peak funding requirements to occur in FY 1992. The program's Critical Design Review is scheduled for completion the first quarter of CY 1992. By the fourth quarter of that year, our work package system and element hardware is scheduled to begin integration and assembly.

Benefits

It is difficult to determine which of Space Station Freedom's many benefits is the most important to our nation. There are many different features of the program that benefit many different segments of our society that I will not attempt to prioritize the individual merit of each benefit. The true value and benefit of Space Station Freedom, I feel, is the total collection of these many benefits.

Two of the earlier users aboard Freedom are likely to be materials processors and biomedical researchers. The microgravity space environment enables materials research which could potentially lead to new supercomputers, high strength alloys, and improved pharmaceuticals. In-space biomedical research for long duration space flight has the potential for delivering health care benefits on Earth. As an example, research to control bone calcium loss in space could lead to a control for bone calcium loss on Earth, improving life particularly for the elderly.

Space Station Freedom is a permanent observatory for Earth sciences and astronomy. Earth observations from Freedom will contribute to "Mission to Planet Earth," providing a global understanding of our ecological system. This observation and data collection capability can contribute significantly to developing solutions for environmental problems such as air and water pollution, deforestation, the greenhouse effect, ozone depletion, and waste and resource management.

The Space Station is key to revitalizing U.S. science and engineering education. Freedom provides today's school children with a vision of their future, and inspires future generations of Americans to pursue excellence in education and the expansion of knowledge. In addition, the ability to perform real-time research aboard the Space Station in response to new and innovative ideas motivates space science research at our colleges and universities.

Space Station Freedom also serves as a stepping stone to our nation's future space endeavors. It serves as an in-space testbed to develop advanced exploration technologies as well as to study the long term effects of the space environment on humans. When our Nation chooses to pursue human exploration beyond low Earth orbit, Freedom functions as a staging base for large structure assembly, spacecraft servicing and refueling.

One can make an analogy between Freedom and our national aeronautical research centers, such as the Langley Research Center, built earlier this century to perform basic aeronautical research. As a result of this research, our nation grew from the first flight at Kitty Hawk to today, where air travel and transport are a normal and important part of our everyday lives. One cannot say whether the military, the commercial airline industry, or others benefitted the most. They each benefitted and our Nation benefitted. Space Station Freedom is a national space research center that will benefit our Nation in the 21st century.

At the time the facility at Langley Field was built, no one imagined these wind tunnels spawning the multi-billion dollar commercial airline industry we know today. Similarly, many of Freedom's benefits are unknown, waiting to be discovered and developed. The most exciting potential lies in these serendipitous discoveries that capitalize on human creativity in the unique space environment. These new, but currently unimagined, capabilities will grow into the technologies and industries of the 21st century.

Program Importance

Space Station Freedom is a fundamental element of NASA's basic infrastructure required for performing most major space missions as the Nation enters the 21st century. It is a cornerstone in the foundation of NASA's "core" programs, which are necessary to ensure America's continued leadership in the sciences, technology, education, commerce, and international cooperation. It is a key to our future competitiveness. The Soviet permanently manned space station Mir has been operating continuously since 1986, and other nations have begun plans to establish permanently manned space centers in the early 21st century. Schedule delays, caused by inadequate or interrupted funding, will cut into the technological leadership that the United States currently enjoys.

Space Station Freedom promotes the commercialization of space. One of the current barriers to space commercialization is the high cost and lack of access to in-space research and development. In order to develop the necessary technology, many potential commercial space products require the capability and efficiency of manned research and development laboratories in space. This capability becomes available with the completion of Space Station Freedom.

The United States has developed the strongest aerospace industry in the world, providing a significant trade surplus since World War II. The trade balances in our low and medium technology industries have been negative for several years. Even our high technology trade balance has declined steadily since the early 1980's, although it is still on the positive side. However, the aerospace balance of trade is not only positive, but still increasing. We cannot afford to lose this competitive edge.

I would like to thank the Chairman and Members of the Subcommittee for giving me this opportunity. In summary, I wish to reiterate that the Space Station Freedom program is firmly in place and making timely and effective progress to meet the challenge of establishing a permanently manned capability in the fourth quarter of 1996. We in industry are proud to be involved in this Nation's future.

Senator GORE. Thank you for your testimony. And in your forbearance in the 50 items you did not cover.

Mr. THOMPSON. I slipped a few of those into my written testimony.

Senator GORE. Well, we will read that carefully.

Dr. Lawrence Greenwood is general manager for spacecraft operations at Astro Space Division of G.E.

Welcome. Please, proceed.

STATEMENT OF LAWRENCE R. GREENWOOD, GENERAL MANAGER, SPACECRAFT OPERATIONS, ASTRO SPACE DIVISION, GENERAL ELECTRIC CO

Dr. GREENWOOD. Thank you, Mr. Chairman. I am pleased to be here to discuss the activities of General Electric relative to Work Package 3 of the Space Station Program.

I would like to submit a complete statement and briefly summarize it here.

We recognize that a permanently manned base in orbit is necessary for the United States to reestablish its leadership in space research and development. As an investment in the future, Space Station Freedom will continue to enhance our national science and technology base and contribute to our economic well being. It is the next step in the development of our national space infrastructure and leads to opening the frontier of space for further development.

At General Electric, we are working with the Goddard Space Flight Center in completing the preliminary design of Work Package 3 elements and systems. These include the U.S. platform, which enables the Earth observation system program specifically designed to facilitate Mission to Planet Earth accommodations for external payloads on the manned base, continuing studies of servicing facility design as part of the planned evolution of the Space Station Freedom, and planning for the integration process of the flight telerobotic servicer.

During the past two decades, we have begun to realize that man can change our global environment. Concern over global warming and ozone depletion have led us to begin to develop the tools to analyze the Earth as a system. Space technology has now matured to the point that Earth orbiting satellites can provide the data base needed to verify the analysis of possible global change.

The polar orbiting platforms are key to making the measurements needed in the next decade. The first application of this platform is planned as part of the Earth Observation System.

Another part of the Work Package 3 is the attached payload accommodations equipment, which enables scientific and commercial user access to the manned base resources and mounting to the space station truss assembly, their primary mission being to facilitate physical sciences on the manned base; plasma, physics, astronomy and earth sciences.

Working with Goddard and with TRW, our major subcontractor, we are making good progress in the program goals of this work package. We have completed, during the past year, a preliminary requirements analysis and are presently involved in a review of the conceptual design. We are moving towards a preliminary design review next year and a launch as early as late 1995.

Our position in space is being strongly challenged. The Europeans and Japanese have made tremendous strides in their abilities to manage and develop successful space endeavors. The platform being developed as part of the Space Station Program would be a giant step in regaining this leadership. The platform represents major advances in spacecraft autonomy, advanced computer systems, modularity, payload servicing, replenishment and growth. It will be the future platform for many experimental and operational payloads thereby increasing the competitive position of the U.S. for future space missions.

The American space program has proven to be a wise investment over the past three decades. It has contributed successfully and significantly to our economic welfare and our national spirit. We must continue forward with Space Station Freedom to maintain the momentum of our space endeavors, which will be an essential part of the American future.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF DR. LAWRENCE R. GREENWOOD, GENERAL MANAGER, EAST WINDSOR OPERATIONS, GENERAL ELECTRIC ASTRO-SPACE DIVISION

We recognize that a permanently manned base in orbit is necessary for the United States to re-establish its leadership in space research and development. As an investment in the future, Space Station Freedom will continue to enhance our national science and technology base and contribute to our economic well being. It is the next step in the development of our national space infrastructure and leads to opening the frontier of space for development.

We are working with the Goddard Space Flight Center in completing the preliminary design of Work Package 3 elements and systems. These include the U.S. Platform which enables the Earth Observation System Program specifically designed to facilitate "Mission to Planet Earth", accommodations for external payloads on the manned base, continuing studies of Servicing Facility design as part of the planned evolution of the Space Station Freedom, and starting the integration process for the Flight Telerobotic Servicer.

It is essential that Space Station Freedom program activities continue to be fully funded if our initial efforts are to result in a cost effective program. We have negotiated a contract with the GSFC within the scope of the NASA budget envelope. A program responsive to the needs of the User community that considers the impact of decisions on total life cycle cost has been defined, its schedule and budget established. Our present need is for an adequate, predictable and stable funding profile that extends beyond the current year to allow planning for efficient utilization of manpower and facilities. The program is moving forward and such a funding committment would assure that it continues to progress as planned.

The unmanned Platforms provide a facility for the investigation of earth, solar and stellar phenomena. Development of Platforms will provide the nation with the largest, most versatile spacecraft built to date. Its first application is in support of the Earth Observation System (Eos) program which will greatly enhance our scientific knowledge and expand our basic understanding of the Earth, its environment and its climate. The program is a cooperative effort involving ESA and Japan. The Eos platforms will carry 50 payloads, 30 of which are nominally planned for the US provided platforms.

Attached Payload Accommodations Equipment enables scientific and commercial User access to the manned base resources and mounting to the Space Station truss assembly. Their primary mission is to facilitate physical science on the manned base; plasma physics, astronomy and earth sciences.

The Space Station Servicing Facility to be incorporated in a later phase, would accommodate and use the Flight Telerobotic Servicer providing a valuable and versatile adjunct to Space Station Freedom.

In addition to the technological benefits to be derived from the Space Station Freedom Program, we are developing the next generation of technical managers capable of directing large, complex aerospace programs with multiple interfaces, international participation. The program will also have a positive motivational influence on education revitalizing interest in science and engineering careers.

Our position in space is being strongly challenged. The Europeans and Japanese have made tremendous strides in their abilities to manage and develop successful space endeavors. The Platform being developed by GE is a giant step in regaining this leadership. The platform represents major advances in spacecraft autonomy, artificial intelligence, advanced computer systems, modularity, payload servicing, replenishment and growth. It will be the future platform for many experimental and operational payloads thereby increasing the competitive position of the U.S. for future space missions.

We have all recognized that space holds enormous potential for commerce. The administration supports private sector investments in space with specific policy guidelines and instructions. However, despite the best efforts of NASA to promote the commercialization of Space, their efforts will be relatively unsuccessful unless changes are made to government/industry relationships.

Other countries have recognized the need for policies encouraging commercial enterprises in space programs and are in an excellent position to compete with American companies for those future markets.

The American Space Program has proven to be a wise investment over the past three decades. It has contributed significantly to our economic welfare and our national spirit. We must continue forward with Space Station Freedom to maintain the momentum of our space endeavors which will be an essential part of the American future.

Senator GORE. Thank you very much. We will have questions later.

Mr. George Hallinan is vice president for space station power at Rocketdyne.

Welcome, Mr. Hallinan.

STATEMENT OF GEORGE J. HALLINAN, VICE PRESIDENT FOR SPACE STATION POWER, ROCKETDYNE

Mr. HALLINAN. Mr. Chairman, distinguished members, thank you for this opportunity to speak with you about our important national program, Space Station Freedom. This work package is managed by NASA Lewis Research Center in Cleveland, Ohio.

We at Rockwell International feel strongly that if we are to meet the station's future goals in space and assure continued U.S. leadership, we will require a permanently manned space facility, the Space Station Freedom, as a crucial element of America's space system and capabilities infrastructure.

My job in Space Station Freedom is to generate, store and distribute cost-effective electric power to the station, its users, including the polar platform. In the current Phase 1 program, power is generated by large photovoltaic solar arrays made up of many large solar cells which convert solar energy to DC power. For growth, power will be generated by a more efficient system called solar dynamic power, which converts solar energy to heat a gas, which drives a turbine to generate required power.

When implemented, the solar dynamic process will provide a dual-power source and will be the key to safe, long-term effective operations in responsiveness to user needs.

Work Package 4 has made significant progress this year. We are on track with the fiscal year 1989 dollars you have provided. In engineering, our requirements document and interface document are complete, and lower-level specifications are approximately 50 percent complete.

We are engaged in the design of individual components and are currently constructing engineering test hardware. Of 14 electric components, eight are presently in some form of construction or tests; and good progress is being made on our remaining six.

At Rocketdyne, we have completed seven major purchase orders for electrical components for our test laboratories, the largest one, with Westinghouse, involves hardware such as transformers, converters and remote isolators due to be delivered starting this month.

Our team members are also well underway in their efforts. For example, Lockheed, who builds the photovoltaic solar arrays, has placed two purchase orders with separate companies for solar cells.

Ford Aerospace has placed two key purchase orders with separate suppliers for battery cells. The Work Package 4 team has set up two major test facilities which are now in operation. The first, Rocketdyne's 35,000 square foot space power development laboratory, took delivery in October of three advanced computer systems, making it our country's most capable space power development laboratory.

The second was dedicated in January of this year at NASA Lewis. This power system's facility provides for a wide range of electrical power component and system testing. It has the ability to monitor on-orbit power system performance and to simulate any abnormality which occurs in space for analysis and resolution.

We believe firmly that NASA has provided the necessary tools and support services required to assure a successful Space Station Freedom program.

The management structure is in place, and it is working well. Our company commitment is strong and the baseline design is sound and broadly supported, and the program momentum is building.

In January of 1988, our team numbered slightly over 100. Today, we are at 550, which will peak at 1,400 by fiscal year 1991. We need every dollar in fiscal year 1990 to maintain this momentum and to stay on track. When the station is in orbit and operational, it will be a very capable, versatile and productive laboratory facility.

One of the reasons that aerospace continues to be this nation's leading trade surplus performer, almost $17 billion in 1987, is that our technology edge permits us to build a better product. Much of that advantage derives from industry applications of technological advances developed during the past major U.S. space initiatives, which have generally contributed a 7 to 1 pay back in dollars invested.

My prepared text lists a number of these advances.

The bottom line is that, despite overwhelming evidence of benefits received from the civilian space program over its 30-year history, some critics still ask what we will get from the Space Station Freedom. I am convinced benefits will accrue just as surely as they have in the past.

If I may, one final word relative to the issue of space commercialization as it may relate to power. We will continue to study and, in fact, are currently under contract to study any idea that appears to make good business sense, good sense for the United States government and taxpayers, good sense for the Space Station Freedom program development and good sense relative to the safety of the Space Station Freedom's crew.

We appreciate this committee's leadership and support for the Space Station Freedom. What we need now is to keep the program on track. We can do this with your support for full funding in fiscal year 1990.

Thank you.

[The statement follows:]

STATEMENT OF

MR. GEORGE J. HALLINAN
VICE PRESIDENT & PROGRAM MANAGER
ELECTRIC POWER SYSTEM
SPACE STATION FREEDOM

Mr. Chairman and Members of the Subcommittee, I sincerely appreciate this opportunity to discuss our Work Package 04 activity on the Space Station Freedom Program with you. Since our contract award announcement in December of 1987 by NASA Lewis Research Center, we have made significant progress. I thank you for your interest in the program and I welcome this opportunity to share with this subcommittee where I believe we are on the program, and how far we have come in a short period.

If I may take a moment to summarize, our job on the Space Station Freedom program is to generate and distribute electrical power. For Phase I, generation is done with large solar arrays, and for Phase II with a solar dynamic system. During the sunlight portion of the orbit, batteries are charged and later provide power during the eclipse portion of the orbit. We are also responsible to build the electronic equipment to switch from solar arrays to batteries and to convert to 20 kHz for distribution through the Space Station Freedom. At the module or experiment end of the power system, we build the circuit breaker equipment, some what analogous to the circuit breaker on the side of your house.

WORK PACKAGE 04 PROGRAM STATUS

Effort on all fronts within Rocketdyne's Work Package 04 program, and indeed the entire program, are focused on a successful Preliminary Design Review (PDR). Work Package 04 PDR is scheduled with NASA-LeRC in June of 1990, and with Level II in Washington in August of 1990. Accordingly, in 1988, the first full year of Space Station Freedom's development, important program management initiatives were implemented which will ultimately assure a successful PDR, and over the longer term, a successful program.

Major accomplishments have been made in our program subcontracts procurement activity. Rocketdyne and its team members (Allied Signal, Ford Aerospace, Harris Corporation and Lockheed) have completed all contract negotiations. Our remaining team member, General Dynamics, is in negotiation. Our subcontractor LTV has a definitized contract to provide solar dynamic radiators for Phase I test activity.

Several of our team members have placed significant long lead purchase orders. Lockheed has placed two purchase orders with separate companies for photovoltaic solar cells and one for bypass diodes. Allied Signal in Tempe, Arizona, has completed negotiation with their sister division AiResearch in Los Angeles to provide the Closed Brayton Cycle power generation subsystem for Phase I testing. Ford Aerospace has placed two key purchase orders with separate suppliers for battery cells.

Internally, Rocketdyne has placed seven major purchase orders for electrical components for our electrical laboratories. The largest one, with Westinghouse in Lima, Ohio, has electrical hardware such as transformers, converters and remote isolators due to be delivered to Rocketdyne starting this month through May.

In terms of engineering status on the program, several key accomplishments assure an effective PDR. We have completed the overall system design and architecture and we are now engaged in the design of individual components. These are presently being constructed in our laboratories on a "breadboard" basis. Data from these breadboards will be used to finalize the design. Of the 14 principal design packages on Space Station Freedom, 8 are presently in some form of breadboard construction or test.

The Work Package 04 Requirements Document has been baselined and approved by NASA. It defines the performance and operational requirements upon which our design effort now undereway is based. The Electric Power System (EPS) Architectural Control Document (ACD), which defines EPS architecture and interface requirements with the other work packages, has been completed and is being reviewed by NASA Lewis. It is scheduled to be submitted to Level II this month. The ACD is significant in that it baselines work package interface requirements and thereby allows our design and development efforts to proceed in parallel with the other work packages.

Contract End Item (CEI) specifications are nearing completion and are scheduled for review with NASA Lewis in May. Lower level specification and control drawings are approximately 50% complete.

Two significant new facility accomplishments in 1988, which are critical to Work Package 04 success, are in place. On October 11, 1988 Rocketdyne took delivery of three computer systems that make up the heart of the country's most advanced space power development laboratory. The facility, totalling over 35,000 square feet is comprised of six modern laboratories. The three computer systems being integrated into the design and development process are:

- The Software Support Environment (SSE), which provides a rigid configuration controlled environment for developing deliverable software configuration end items
- The 5,500 square foot Simulation Laboratory (SIM LAB), which can display a nearly infinite combination of realtime simulations of Space Station Freedom power applications, events, checkout routines and potential problems for use in crew training for computer and human operation
- The 4,100 square foot Technical and Management Information System (TMIS), a collection of hardware and software that delivers to the desktops of those involved up-to-the-second data on the power project. A key feature is that this system is fully integrated with the NASA TMIS, which spans the entire Space Station Program

The flight software, which will operate the Station's power control system, will be developed on the Software Production Facility computer system. It will be used in power controllers, which will be developed, checked out and integrated with the software in the Microprocessor Development Laboratory and then into a large control system. The SIM LAB computers will be used to develop, integrate and check out the entire power control system using high fidelity high-speed simulation of the entire Station and associated power systems. The simulations run on the computer systems will be integrated with actual hardware operating in the Microprocessor and High Voltage Laboratory.

High voltage electrical components will be developed and tested in the Electronics Laboratory with a special grounding system. A large second generation Space Power Electrical Laboratory will be used to integrate and test the actual high voltage electrical system.

The other key facility, dedicated last January 9, 1989 was NASA Lewis' Power System Facility (PSF).

The PSF was constructed for the development and on-orbit operating support of the Space Station Freedom electrical power system. The PSF, Lewis' newest facility, provides for a wide range of electrical power component and system testing.

The PSF has several areas with unique features. These areas include the main test area, the Ni-H_2 energy storage room, and the test cell. The main test area is an 8,300 square foot high bay area with a 55 foot clearance below a 10 ton crane. This test area can operate as a class 100,000 clean room that is capable of removing 90 percent of the airborne particles.

The PSF utilizes an adjacent solar array field for power system and component testing. The solar array field consists of 960 silicon solar cell modules. The maximum array power is 30 kilowatts at 160 volts.

Hardware for the tests to be conducted in the PSF include NI-H_2 batteries, solar concentrator mirror, and power management and distribution (PMAD) system and components. The PSF will include an engineering support center (ESC) to permit monitoring on-orbit power system performance. The ESC will have the capability of simulating any anomalies experienced in space for analysis and resolution.

A final important accomplishment was the Associate Contractor Agreement (ACA) effort implemented by the NASA Space Station Freedom Associate Administrator, Mr. James Odom. Mr. Odom recognized that program integration could be significantly enhanced and program schedule risk diminished by direct interface between prime work package contractors. These ACA's are now in place. Working together, the prime contractors, Boeing, G.E., McDonnell Douglas and Rocketdyne, are identifying detailed interface and scheduling mismatches and are working to resolve them. This effort has resulted in the development and initial submittal to Level II, on the first of this month, of the programs first intersite delivery list and schedule document, coordinated among all prime contractors. To support this activity, Rocketdyne established the position of Associate Interface Manager to lead this effort for our program office.

In the middle of 1988, Rocketdyne also established a dedicated staff of integration engineers at our Cleveland office, plus representatives from other program functions. This staff has been located in a new facility just outside the main gate of NASA Lewis. Effective day-to-day integration activity will be enhanced by the local availability of this staff to our customer.

WORK PACKAGE 04 NEEDS AND REQUIREMENTS

We believe firmly that NASA has provided the necessary tools and services required to assure a successful Space Station Freedom program. The management structure is in place and it is working. Contractor commitment is high, morale is good, the baseline design is sound and broadly supported and program momentum is building.

In January of 1988, direct charging personnel to the program for Rocketdyne and its team members was at a level slightly over 100. Today it is approximately 550. By the end of this September it will be approaching 1000. Average headcount in FY90 will be approximately 1400.

This staffing profile is what we believe it will take to most cost effectively get the Space Station Freedom program done. It assumes release no later than May of remaining FY89 budget, and full funding of the FY90 budget request of $2.05 billion. This staffing profile was structured to the current program schedule termed "Mod 12" which recognized constrained funding for the first 8 months of this fiscal year.

With the progress we have made, and the momentum that has been generated in long lead procurement, testing and test facilities, preliminary design, requirements and interface specification development, and staffing, there is no doubt that the one remaining "need" or "requirement" for Work Package 04 is full funding for FY90, and a commitment to the proposed $8.5 billion for Fiscal Years 1990 through 1992. Anything less at this point in the program will most certainly result in major perturbations to the program in terms of cost and schedule. On the other hand, this subcommittee's continued support for full funding will assure we will launch first elements in early 1995 and we will do it within committed cost.

WORK PACKAGE 04 PROPOSED SCHEDULE AND BUDGET PROFILE

Figure 1 is the current Work Package 04 Master Integrated Schedule. (Figure 1A is the "Key Hardware Schedule" for 1989 and 1990.) On Figure 1, the next major program milestone, as previously discussed, is Preliminary Design Review (PDR) scheduled for August 1990, followed by Critical Design Review (CDR) in May of 1992. Phase II contract start date (PH2 CSD) of January 1992 is contingent upon congressional go-ahead in 1991.

The Photovoltaic (PV) system development, production and delivery schedule supports a first element launch (FEL) of March 1995. The PV power module system is currently scheduled to launch on flights 1, 5 and 13 (designated MB-1, MB-5 and MB-10, respectively). The solar array is built by Lockheed and is built around the technology that was demonstrated by NASA on the Space Shuttle, Mission 41-D.

The solar dynamic (SD) power module system in Phase I includes preliminary design and definition and power generation system (PGS) proof-of-concept tests. These tests start in late 1990 and continue through into 1993. If Congress approves proceeding with Phase II,

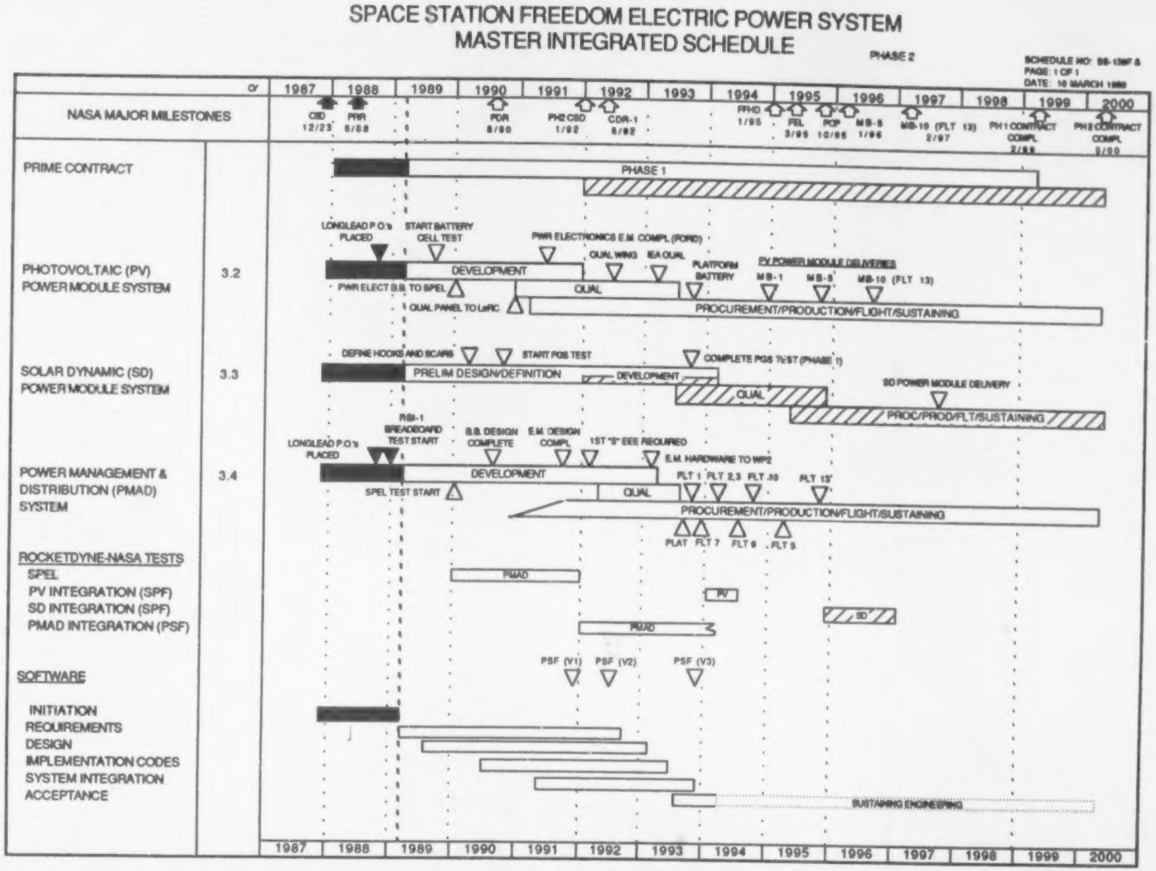

SPACE STATION FREEDOM ELECTRIC POWER SYSTEM
MASTER INTEGRATED SCHEDULE
PHASE 2
SCHEDULE NO:
PAGE: 1 OF 1
DATE: 10 MARCH
CY
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
NASA MAJOR MILESTONES
CSD 12/23
PRR 5/88
PDR 8/90
PH2 CSD 1/92
CDR-1 8/92
FFHD 1/95
FEL 3/95
PCP 10/95
MB-5 1/96
MB-10 (FLT 13) 2/97
PH 1 CONTRACT COMPL 2/99
PH 2 CONTRACT COMPL 9/00
PRIME CONTRACT
PHASE 1
PHOTOVOLTAIC (PV) POWER MODULE SYSTEM
3.2
LONGLEAD P.O.'s PLACED
START BATTERY CELL TEST
PWR ELECTRONICS E.M. COMPL (FORD)
QUAL WING
IEA QUAL
PLATFORM BATTERY
PV POWER MODULE DELIVERIES
MB-1
MB-5
MB-10 (FLT 13)
DEVELOPMENT
PWR ELECT B.B. TO SPEL
QUAL
QUAL PANEL TO LeRC
PROCUREMENT/PRODUCTION/FLIGHT/SUSTAINING
SOLAR DYNAMIC (SD) POWER MODULE SYSTEM
3.3
DEFINE HOOKS AND SCARS
START PGS TEST
COMPLETE PGS TEST (PHASE 1)
PRELIM DESIGN/DEFINITION
DEVELOPMENT
QUAL
SD POWER MODULE DELIVERY
PROC/PROD/FLT/SUSTAINING
POWER MANAGEMENT & DISTRIBUTION (PMAD) SYSTEM
3.4
LONGLEAD P.O.'s PLACED
RBI-1 BREADBOARD TEST START
B.B. DESIGN COMPLETE
E.M. DESIGN COMPL
1ST "S" EEE REQUIRED
E.M. HARDWARE TO WP2
DEVELOPMENT
SPEL TEST START
QUAL
FLT 1
FLT 2,3
FLT 10
FLT 13
PROCUREMENT/PRODUCTION/FLIGHT/SUSTAINING
PLAT
FLT 7
FLT 9
FLT 5
ROCKETDYNE-NASA TESTS
SPEL
PV INTEGRATION (SPF)
SD INTEGRATION (SPF)
PMAD INTEGRATION (PSF)
PMAD
PV
SD
PMAD
SOFTWARE
PSF (V1)
PSF (V2)
PSF (V3)
INITIATION
REQUIREMENTS
DESIGN
IMPLEMENTATION CODES
SYSTEM INTEGRATION
ACCEPTANCE
SUSTAINING ENGINEERING

FIGURE 1

SPACE STATION FREEDOM ELECTRIC POWER SYSTEM

KEY HARDWARE SCHEDULE

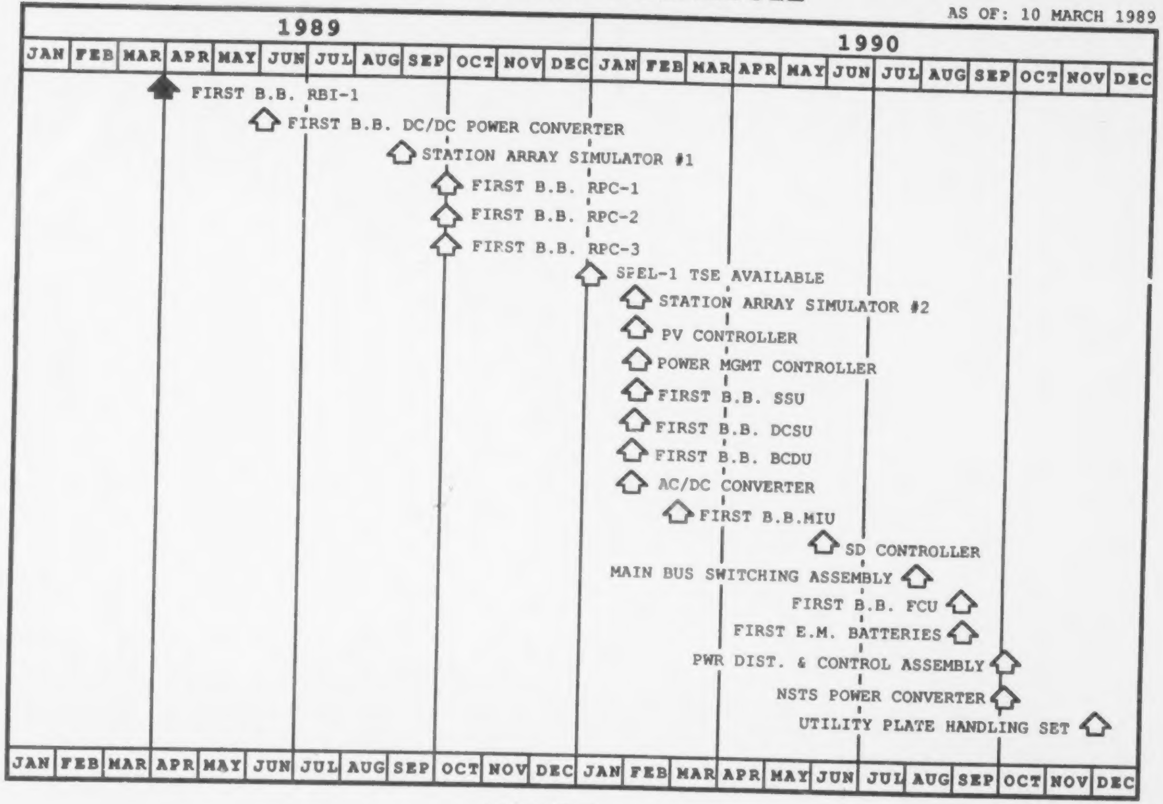


FIGURE 1 A

development of SD would start January of 1992 and be ready for launch late 1997, providing an additional 50 kW of power. Extensive analysis during Phase B determined that the most cost effective way to grow power on Space Station Freedom was via SD rather than via PV.

The power management and distribution (PMAD) system deliveries are shown as milestones on the "procurement" activity bar. Test activities are initiated the first of 1990 in the Space Power Electronics Laboratory (SPEL) at Rocketdyne involving primarily subsystem circuit and switchgear testing. Integration testing will be done at NASA Lewis Solar Power Facility (SPF) at Plumbrook outside of Cleveland, Ohio. PMAD system integrated testing will be done at NASA Lewis Power System Facility (PSF) starting in 1992. This facility was dedicated at NASA Lewis on January 9, 1989. Other test activities planned at the PSF are already underway as indicated on the attached "PSF Activities" charts.

Planning for software development has essentially been completed. Requirements definition and design are major 1989 activities in this area.

Figure 2 identifies the man loading profiles for Rocketdyne and our team members by month for FY88 and FY89, and by year for the entire contract period. Figure 3 shows the expenditure projection for the program. These profiles were developed to the current NASA Lewis program baseline termed "Mod 12" (31 March 1985 FEL).

IMPORTANCE OF SPACE STATION FREEDOM

One of the reasons that aerospace continues to be this nation's leading trade surplus performer (almost $17 billion in 1987) is that we build a better product, in all aspects. Much of the advantage derives from the industry application of technological advances developed during past major U.S. space initiatives. No one predicted in the early days of the Apollo or Shuttle programs what advances would accrue, but they did, and they accrued not only to aerospace, but to industries across the board:

- Hospital sensors developed in the 1960's to monitor astronauts' respiratory gases during Gemini and Apollo, which today are the heart of remote monitoring systems found in hospitals across the nnation.
- Computers being trucked to new locations riding safely on air-bearing floors, developed initially as a simple air-bearing pad first used to move multi-ton components of Saturn rockets around the factory floor.
- Johnson Space Center technicians using space age materials to develop lightweight air packs, used by all major air pack manufacturers today.

SPACE STATION PROGRAM TEST ACTIVITIES AT LEWIS RESEARCH CENTER

POWER SYSTEM FACILITY (PSF) ACTIVITIES

JAN 89 - MAY 89

- HARRIS SOLAR DYNAMIC CONCENTRATOR ASSEMBLY REPEATABILITY TEST

  Assemble, Align, Disassemble, Reassemble & Verify Alignment

MAY 89 - SEPT 89

- LeRC BUILD & ACTIVATE THE 20 kHZ POWER MANAGEMENT & DISTRIBUTION (PMAD) SUPPORT LAB
- LeRC INSTALL 20 kHZ TEST BED INTO THE SUPPORT LAB

SEPT 89 - APR 91

- LeRC DIGITAL IMAGE RADIOMETER TEST FOR SOLAR DYNAMIC CONCENTRATOR

  Re-orient Concentrator & Fully Populate for Digital Image Radiometer Test

SPACE STATION PROGRAM TEST ACTIVITIES AT LEWIS RESEARCH CENTER

PSF ACTIVITIES (continued)

APR 90 - SEPT 90

- LeRC, Rocketdyne, Ford NICKEL HYDROGEN BATTERY LAB ACTIVATION

SEPT 90 - SEPT 95

- LeRC, Rocketdyne, Ford NICKEL HYDROGEN BATTERY PACK LIFE CYCLE TEST

SPACE STATION FREEDOM
FY-88 & 89; MOD 12 SCHEDULE
ROCKETDYNE AND TEAM MEMBERS

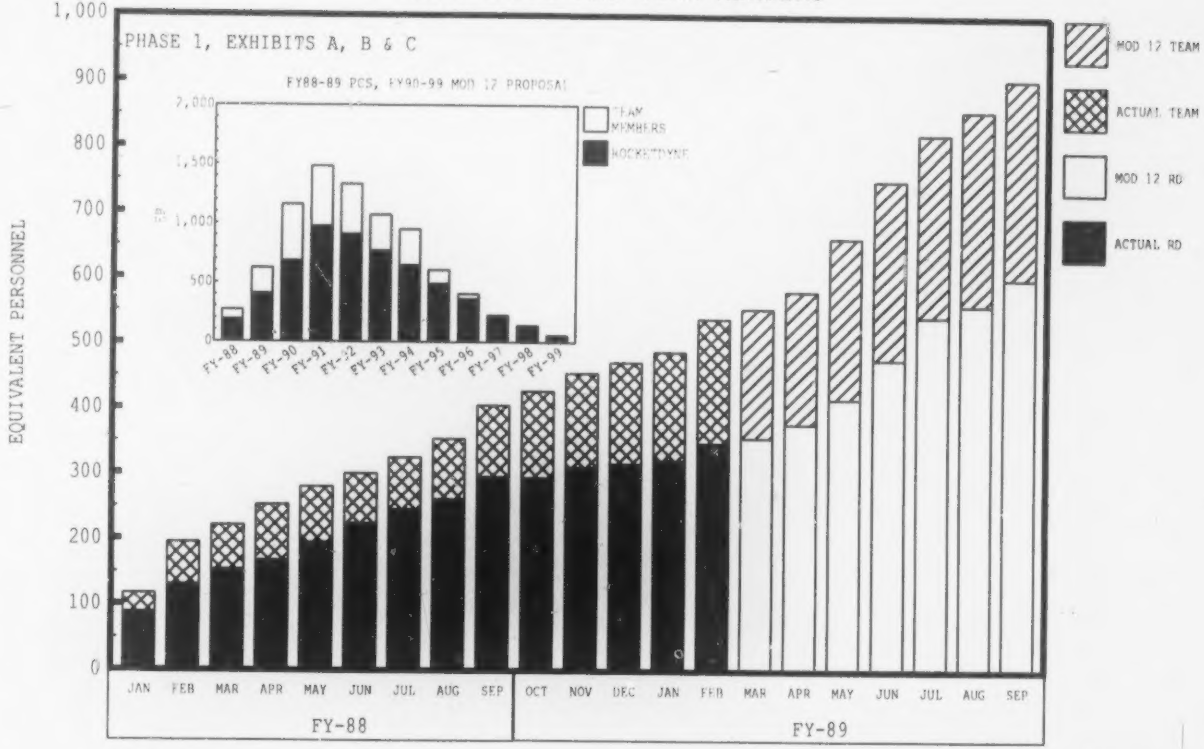


FIGURE 2

D/654, 03-10-89
PCS JAN MO END
C:\WEEKLYEP\BRIEF

SPACE STATION FREEDOM
ROCKETDYNE WP-04
EXPENDITURE PROJECTION

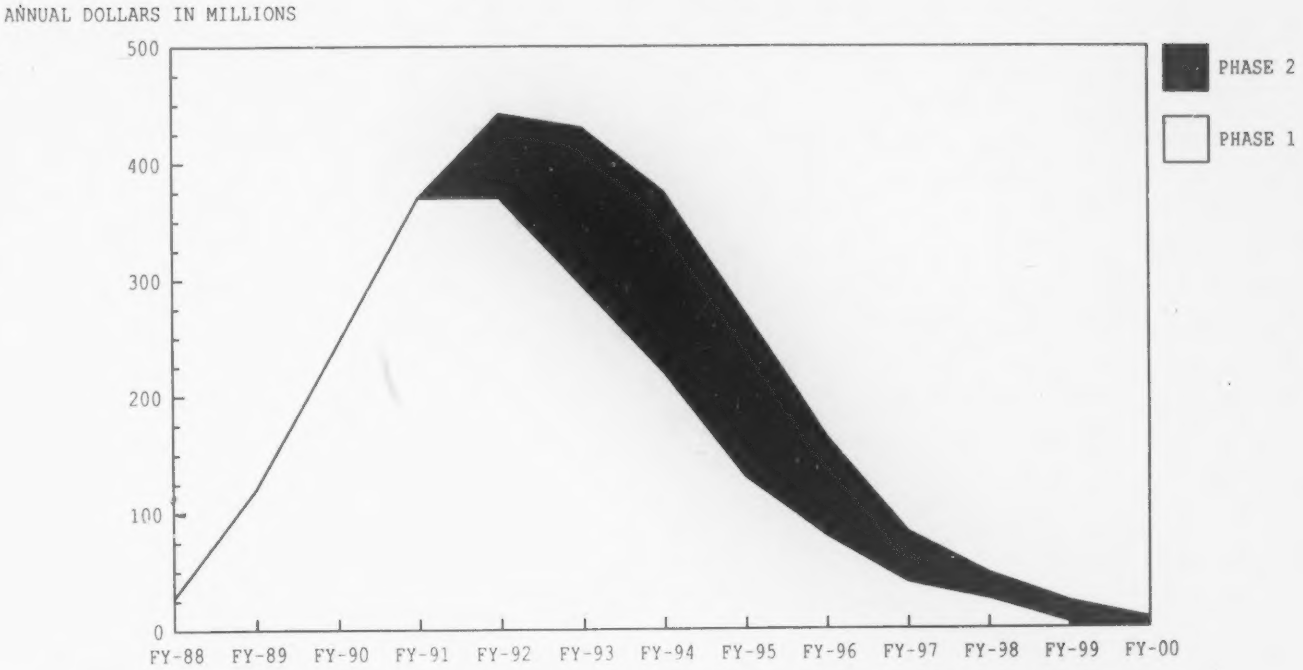


FIGURE 3

JMH051
3-10-89
TOTAREA.CHT

- A simple and elegant data base program developed at the Jet Propulsion Laboratory for planetary missions modified to run on desktop computers. In its latest version, the best selling dBase III program is a popular favorite for users of both MS-DOS and Macintosh computers.

- Beta Yarn is a thin glass fiber yarn developed to be woven into space suits. Coated with Teflon-TFE, the resulting fabric is strong, lightweight, weatherproof and fire resistant and serves as the roof for structures ranging from 80,000-seat Silverdome in Pontiac, Michigan, to a department store in San Jose, California. The material does not require cleaning and costs less than half of conventional roofing.

- Technology from a pair of unrelated NASA programs, the Viking Program that landed two science-laden spacecraft on Mars in the mid 1970's and the Small Astronomy Satellite Program, combined to produce a medical miracle that holds the promise of freeing diabetics from daily injections.

  The programmable inplantable medication system (PIMS), developed by the Johns Hopkins Applied Physics Laboratory with major technical assistance and funding from NASA's Goddard Space Flight Center, is a device the size of a hockey puck that automatically supplies insulin in the required dose and at the programmed times. PIMS uses miniaturized electronics developed for Viking, and communications and programing technology developed for the astronomy satellite.

  The device is worn externally and contains a three-month insulin supply which can be easily refilled.

- A computer program developed at NASA's Goddard Space Flight Center in the 1960's was so advanced for its time that its use was limited to analyzing and solving structural problems related to space missions. But NASA's NASTRAN program soon opened the way for private industry to capitalize on the power of the computer, while saving untold expense and eliminating over the years missions of manhours of effort.

  Continually updated and modified to run on the latest available computers, NASTRAN continues after more than 20 years to be the premiere structural analysis program in existence. As a design and analysis tool, it is used today in the automotive and aircraft industries, in architecture and plant design, and in scores of other applications and fields, including space.

- Heat pipes first developed to radiate waste heat away from satellites were incorporated into structural supports along the Alaskan pipeline, where they prevent warm oil from thawing the permafrost and perhaps triggering a collapse and pipeline rupture. Heat pipe technology, grown from satellite size to Alaskan standards, helps prevent an ecological disaster of the first magnitude.

- Sky-Lab Foods, Inc., in White Plains, N.Y., is a small business that provides freeze-dried meals by mail order to elderly customers. The company packages its meals using a process developed by NASA to feed astronauts in space.

- Computerized techniques developed to enhance images sent by satellites have led to extraordinary advances in medical imaging and are routinely used with such state-of-the-art imaging technologies as nuclear magnetic resonance (NMR) imaging. The techniques also are in the movies, used in advanced special effects, composite scenes, and computer generated effects produced by such masters as George Lucas.

- Water hyacinths seem far-removed from the space program. But NASA scientists, looking for efficient and practical ways to treat and recycle wastewater during long-duration space flights, discovered that the plants feed on effluents and yield clean water. The techniques they developed for using water hyacinths to treat sewage were tested in pilot plants in San Diego and at Epcot Center, and are now incorporated into permanent facilities at those locations and elsewhere.

- One of the many details scientists tackled in sending men and machines into space was finding a way to protect camera and instrument lens, windows and astronaut helmets from being scratched by space dust and other particles. The coating developed at the Jet Propulsion Laboratory proved so effective that NASA licensed it to the Foster-Grant Company, which now markets lightweight sunglasses with plastic lens. The coated lens are equal to glass lens in resisting scratches and abrasions, and the products are so successful that the license is one of NASA's top commercial revenue-producers.

- Air travel is increasingly safe with the advent of automated cockpit warning systems that provide pilots with instant alerts of malfunctions or problems. One system, the Engine Indication and Crew Alerting System (EICAS), was developed with the help of scientists, engineers and simulators at NASA's Ames Research Center. EICAS is now standard equipment on many new airliners, including Boeing's 737 and 767, and the McDonnell-Douglas MD-80.

- At NASA's Goddard Space Flight Center, space scientists developed a low-intensity imaging device that works like an X-ray, but emits little radiation. Now used in medicine under the name Fluoroscan, the device allows doctors to see bones or foreign objects in real time while performing some kinds of surgery.

- Thousands of handicapped Americans owe their mobility or other improvements in their daily lives to space technology. A vehicle controller called Unistick was adapted from the Lunar Rover driven by astronauts on the Moon. Installed in any car or van, it lets the handicapped control all vehicle functions - steering, braking, accelerating - through a one-handed control stick.

  A 25-pound collapsible wheelchair with the strength and capacity of larger and heavier wheelchairs was developed after computerized analysis with aerospace structural programs. The wheelchair also uses lightweight composite materials first developed for spacecraft.

> Using optical-electronic technology developed through space research, blind people can read ordinary print. Optacon is a machine that "reads" print, then sends and puts vibrating images of letters and words on a screen where the blind can read by touch.
>
> Other devices for the handicapped that began with space research include voice controllers for wheelchairs, speech aids for the deaf and voice input devices for home computers.

The lists could go on and on. A quick look at other space benefits includes:

- An experimental laser system that cleans clogged arteries.
- Cardiac pacemakers that can be recharged remotely.
- Ultrasound instruments that monitor human heart functions externally.
- Improved highway guard rails and road surfaces.
- Fire-resistant insulation being used on cables in mass transit systems.
- Dental braces made of a nickel-titanium alloy called Nitinol developed for spacecraft and which returns to its original shape after bending.
- Gas analyzers used to measure automobile emissions and other air pollutants.
- A handyman's home welder that is lightweight, portable and produces a 5,000°F flame.
- Fuel cells first developed in the Gemini program that have been enlarged and improved to produce industrial or utility electricity.
- A widely-used power controller that adjusts electricity use according to demand.
- Propfan engines for commercial jetliners that significantly reduce fuel consumption and will begin appearing on aircraft in the early 1990's.

The point is that despite overwhelming evidence of benefits received from the civilian space program in its 30-year history, and massive testimony about the benefits yet to come from the Space Shuttle and the Space Station Freedom, some critics cling to the fiction that "no one can say what we'll get from the Space Station". If they want someone to say that we'll get a better ballpoint pen or absolutely find a cure for a certain disease, they are right. No one will say that.

In 1958, no one would say that the world will be able to watch the olympics live on television.

In 1968, no one would say that commercially available space photos would one day help shed the light of world publicity on a Soviet nuclear disaster.

In 1978, no one would say developments in space communications would lead to music reproduction of unprecedented clarity and fidelity.

And in 1989, no one can make these kind of wild and unbelievable predictions of the kind of benefits that will accrue from Space Station Freedom. The men and women in NASA, in the industry, and you, the distinguished members of the United States Senate who legislate in the space arena, understand and can articulate the broad goals and purposes of Space Station Freedom:

- A national laboratory for Life Sciences
- A transportation node
- A microgravity laboratory
- A permanent facility for humans
- An outpost for future expansion
- Evolutionary
- A science platform for planned experiments
- A control center
- An earth observation facility
- A national focus
- A commercial opportunity
- An international facility

We can talk of enabling microgravity research and technology relative to:

- Manned Systems
- Materials Processing
- Health Maintenance
- Biotechnology
- Biomedical

- Human Factors
- Long Duration Space Flight

Because the Space Station Freedom program s this nation's next major initiative in space, with international partners, there is no doubt that media coverage as the station develops, is assembled in space, and becomes operational, will be substantial internationally. Because of this exposure, it is almost certain that Space Station Freedom will:

- Excite the young to pursue careers in the biomedical, physical sciences, engineering and aerospace.
- Provide the visual media to the American people with a "window" to space construction.
- Provide national pride and positive views of the direction of this nation in space by sharing the development with the public (especially the young).
- Prompt school teachers around the world to make the Space Station Freedom a "contemporary" subject.

What we cannot do, those of us so close to the Space Station Freedom program is make those wild, wonderful, unbelievable predictions about the benefits that will accrue, but they will just as sure as you and I are here today. Benefits that will create hundreds of thousands of jobs, and assure future competitiveness and technological leadership for not only the aerospace industry, but many others as well. The history of the U.S. civilian space program and its monumental contributions to the economy and to the health, welfare, enjoyment and quality of life of its citizens, shows that any prediction can come true and that the most important and far-reaching of future benefits are beyond today's limited imaginations. We must get this message out.

If I may, one final word relative to the issue of space commercialization. This subject enjoys some popularity these days. As it may relate to potential commercialization of Space Station Freedom power, I want to simply state that we have, and we will continue to study any idea that appears to make good business sense, good sense for the United States government and tax payers, good sense for the Space Station Freedom program development, and good sense relative to the safety of the Space Station Freedom's crew. So far we have not found one, but we will continue to look.

Thank you for your support of this nation's Space Station Freedom program. Please help us keep it on track.

Senator GORE. Thank you very much.

I have a few questions, very few questions on this first round, then, I will go to Senator Lott.

First of all, I was looking at the comparative capabilities of the U.S. proposal and the current Soviet Mir Space Station. The Mir, they have planned for the mid-1990s and the CDSF, and I just find it amazing that a nation with one-third of the U.S. GNP can build a space station and do it well. And yet, many members here argue that we cannot afford one.

It is just remarkable to me, and without objection, I will put this chart on comparative capabilities in the record.

[The chart follows:]

Comparative Capabilities

	Space Station	Current MIR	Mid-90s MIR	CDSF (ISF)
RESOURCES				
■ Pressurized Elements	4	2	6	1
■ Total Pressurized Volume	32,140 ft^3	6,230 ft^{3*}	14,928 ft^{3*}	2,500 ft^3
■ Power	75 kW	5-8 kW*	10-16 kW*	8.5 kW
■ Logistics Flights Per Year	5	10	15*	3
CHARACTERISTICS				
■ Crew Time	30,040 mh/yr	6,006 mh/yr	18,018 mh/yr	396 mh/yr
■ Permanently Manned	Yes	Yes	Yes	No
■ Self-Contained Life Support System	Yes	Yes	Yes	No
■ Platforms	2	1	?	0
■ International Partners	Yes	No	No	No

**U.S. Estimated Value Based on Published Data*

Senator **Gore**. Dr. Greenwood, I was interested in your statements on commercialization. Let me quote from your statement, "However, despite the best efforts of NASA to promote the commercialization of space, their efforts will be relatively unsuccessful unless changes are made to government-industry relationships."

Can you elaborate on that and help us understand what changes you would like to see?

Dr. **Greenwood**. The history of NASA's effort to commercialize space speaks for itself. There have been several major obstacles to commercializing, a major one being stability in policy and direction, the ability of the government to be able to maintain program direction, and funding support.

In order for commercialization to be successful, we need to find mechanisms such that industry and government can establish partnerships, true partnerships, that both partners can count on over a long period of time.

Senator **Gore**. Do you think they have some unrealistic assumptions built into some of their commercialization initiatives now?

Dr. **Greenwood**. I have only looked at commercialization relative to work package 3. In our work package we have looked at commercialization possibilities for attached payloads and we have found none that make sense. The government is the only customer found. We have not, in our scope of activities, found anyplace where commercialization makes good business sense or good sense for the government either.

Senator **Gore**. Does anybody else want to comment on that?

Mr. **Winch**. This is John Winch from Work Package 1. I would comment that we have submitted a commercialization program from the Boeing Company that is presently under evaluation by NASA. And so I would not—prefer to go into it in detail at this point in time, but such a proposal has been submitted.

Senator **Gore**. All right. Now, let me just say that I am frequently surprised to learn the extent to which our nation's entire aerospace and engineering infrastructure is involved in the space station program.

Could you give us a list of the major subcontractors that are involved with your respective work packages, and specify their role in the overall program and whether or not the necessary funds have been provided to fully involve them in the program?

Mr. **Winch**. We will start and go 1, 2, 3, 4, again. Work Package 1. Our major subcontractors are Teledyne Brown Engineering, who is responsible for assisting us in the integration of materials processing experiments in the laboratory module. Lockheed Missiles and Space Company, responsible for assisting us with the integration of life sciences payloads. Grumman, assisting us in the integration of the habitat module.

In addition to that, we have a number of other subcontractors throughout the country, particularly in the environmental control and life support area. We have been severely limited and have not funded most of those subcontractors at a significant level, pending the May 15 release of additional funds.

Teledyne Brown is the only one that has had any significant funding level. The others are at a very, very reduced level at this point.

Mr. **Thompson**. Again, this is Work Package 2. Thompson from McDonnell Douglas.

We have a number of extremely fine subcontractors working with us, McDonnell Douglas, on the program. There are several critical electronic systems in our work package and we have three companies in the electronics area, and then we have a fourth company in a couple of other areas that I will mention, plus a number of smaller subcontractors and vendors.

The three subcontractors working with us in the avionics area are IBM, Honeywell, and formerly RCA, now General Electric. These are premier companies in the specialty areas that they are working with us on the space station.

In addition, the Lockheed Corporation is teamed with us to work in the active thermal control system and in the extra vehicular activity unit, in other words, the suit and the backpack, the equipment to give the astronauts the ability to operate in the vacuum of space on the outside of the space station.

In addition, we have a subcontract with a relatively smaller company by the name of Astro. It is a wholly owned subsidiary of Spar of Canada, the company providing the Canadian remote manipulator arm for space station. And this company, Astro, is in an excellent position to help us work with the Canadian company and provide the mobile base that the arm operates on as it moves around the truss structure.

In addition, we have a very large number of vendors that will need to be brought on board for a number of specialty subsystems. For example, a number of critical tanks need to be developed. Some critical systems that allow us to take electricity and water and create hydrogen and oxygen, which are two gases very vital to the well-being of the station. And many, many others.

Again, I will not list the several hundred that we could list. The thrust of your question is, have we been able to bring those subcontractors up to speed, and are they positioned to move effectively? We have definitely had to depress their activity at this point in time because of the reduced funding, particularly, the front-end funding constraint in fiscal year 1989.

Hopefully, as we pass the 15th of May, we can bring the program into better balance. And, in fact, we have held back in McDonnell Douglas work to actually bring the subs up probably to a level that this type of funding would not normally have supported just to keep the program in better balance.

I think we have all properly restrained various activity to stay in balance, but we are beginning to put the schedule under some risk if we do not release the funding and do not move on up to the levels that the current NASA budget request would allow in the program.

So, we are very proud of the subcontractors we have on board, we think they are premier in the aerospace industry. We think they will be able to deliver the kind of products that we should have in our space station.

Senator **Gore**. Thank you very much.

Dr. Greenwood.

Dr. **Greenwood**. We have one major subcontractor and that is TRW. Their function in the program is sort of two-fold. In Phase 1, they will be providing the major propulsion system for the platform.

As we move into Phase 2, they have a major responsibility in planning for the servicing facility aboard the manned station.

I would say that, in Phase 1, in their propulsion activity, they have moved out. We have, because of priority in funding, had to constrain them in the planning activity for the second phase. And, certainly, that is something we do not prefer.

Senator **Gore**. Mr. Hallinan.

Mr. **Hallinan**. In Work Package 4, we have six major subcontractors. Lockheed in Sunnyvale, we have under contract and we have given them substantial funding so that they could in turn subcontract out for the solar cells for the program. The progress of the hardware goes from development units to qual units to flight units and the numbers of solar cells that we need on Space Station Freedom, because of the size of the power system, is a very large number; it is over 240,000 cells just for the 75 kilowatts.

And so that is a long-lead item, critical path item. So Lockheed has funding and they have subsequently let contracts for the development of the solar cells.

Similarly, we have let a contract to Ford Aerospace in Palo Alto. They provide the nickel-hydrogen batteries for the program. Again, because we are in low-Earth orbit and energy storage is a big requirement, we have over 1,800 nickel-hydrogen battery cells.

And Ford has taken the funding and has let two subcontracts for the development of those nickel-hydrogen battery cells.

We have let a contract with General Dynamics in San Diego. They make the main inverter unit that converts the DC power generated by the solar cells and the batteries and converts it to 20 kilohertz AC single-phase distribution.

We have let a contract to Allied Signal, they provide the work for solar dynamic Brayton cycle engine work. And they are doing the preliminary design on that.

We have let a contract to Harris Corporation in Melbourne, Florida, and they do the work on the solar dynamic concentrator.

And we have let a contract with LTV in Dallas, Texas. a small contract, they are doing work for the radiator system for the solar dynamic.

Senator GORE. Thank you very much.

Senator Lott.

Senator LOTT. Thank you, Mr. Chairman. And thank you, gentlemen for your time and coming here and presenting these statements.

Since I did not make any comments earlier, I would like to make a couple of observations and then ask just a couple of questions.

You know, I was looking at the budget—well, as a matter of fact, I would like to go back before that. I remember just a few years ago when there was a big debate inside the Administration, the Reagan Administration, with a lot of questions raised at OMB about the Space Station. And I remember specifically the day that President Reagan made the decision: Yes, this is something we need. There are tremendous benefits for us commercially, spinoff technologies, and all that it means for the ability of corporate America to participate and all of the benefits. So the decision was made. And I remember when that decision was made.

And then, looking at the funding, I see here that, in 1989, the appropriation was only $900 million. But I am very pleased that President Bush and the new Administration seems to be escalating and redirecting emphasis and money toward the Space Station with $2.05 billion proposed in fiscal year 1990; $2.98 billion proposed in 1991; and $3.49 billion proposed in 1992.

So, I think that we are seeing now is, after a commitment from the previous administration and this administration to the concept and now to increased funding. This is a very significant development.

And I would like a reaction from any of you about the direction the Administration is going and the dollars that we have here. We asked those questions to NASA officials here earlier, and while you never have all you would like to have, I would think that when you start talking about $2 billion, well, really, $2 billion and then $3 billion and then $3.5 billion, those are significant dollars. And they will move us forward in a very positive way.

Dr. Greenwood, would you like to comment on that?

Dr. GREENWOOD. Yes, Senator. The program now is in a state that it is well planned. The management team is in place. The contractor team, as you have heard here, is in place and committed.

The only thing I would add, and it is a message you have heard before, is the necessity to maintain the planned budget levels. Because, as you have also heard today, starts and stops get very expensive.

And I know there is support in this committee and we hope that it continues.

Senator LOTT. Well, I think we should not take anything for granted because you know there are those who do not share our enthusiasm. The gentleman from Tennessee and I are very much committed to it, as are those that realize what it can mean for the country.

But there are also those, in spite of the Bush Administration support and commitment to it, there are those in Congress and out in the country that are raising very serious questions about the space station.

I attended a meeting this past weekend where some questions were raised. People asked, do we really need this and what is it going to mean to us? Should we put this money in housing and in education and all these other programs, without realizing the benefit we will derive in education and many other areas.

And that leads me to a question, and maybe I could direct it to you, Mr. Winch. You said here in your statement that there were significant related spinoff technologies that are impossible to predict.

Now, I am a new member of the committee. While I have been very interested in NASA for a long time for a lot of reasons, give me a couple of examples of spinoff technologies that are impossible to predict, but a dreamer could imagine.

Mr. WINCH. The major thing that we believe in, by going into zero gravity, you have the opportunity to explore the unknown, to look into things which are not presently identified. What they are going to be, we do not know at this point in time. We can point out some of the things that have been discovered in the medical area, though.

I gave you the examples of some of the work going on in crystallography at the University of Alabama at Birmingham. By developing crystals in space, they are able to develop a crystal, determine what the crystalline structure is, and then develop new medicines which can have application here on Earth.

By looking at crystals, more metallic type crystals, semiconductors can be improved. By looking down at the Earth, we can determine how the weather patterns develop, how they evolve, and potentially have application in terms of the agricultural area.

These are the types of things that I would identify. It is a laboratory environment. As Mr. Thompson I think very correctively observed when we were exploring as a nation with wind tunnels, we had no idea we were going to develop the aeronautical industry, but that has come out of it. It is one of our largest contributors to the U.S balance of payments. The satellite industry that we presently have has come out of the early work on developing satellites. And so I think there will be many very legitimate spinoffs which will happen in the future.

Senator LOTT. I would be glad if any of the rest of you would like to comment on that.

Mr. THOMPSON. Let me just make a comment. You know our nation can choose to develop technology many ways. You can develop it in very small chunks in commercial laboratories and universities. You can develop it in small chunks in government laboratories.

Sooner or later, though, if you do not take on some relatively large technology program like a space station that makes you face up to really developing some new knowledge where you have to then develop the capability of going into some new environment and learning how to operate in that environment.

Until you face up to doing it at this level of activity, you do not really solve either the real problems or develop the real knowledge.

I think it is very clear that our society is not going to survive and the way of life that we prefer is not going to survive if we cannot generate fairly high technology products to sell to the rest of the world. We are not going to compete with the rest of the world with low technology products and sustain our way of living.

And so I think by taking on the challenge of building a shuttle, the challenge of building and operating a space station, and doing the type of research we are talking about will help sustain our technology leadership. We do not want to be too impatient, we have only been in this space business now about 30 years, and we were in the aeronautical business probably more like 45 years before the true industry grew out of it.

So, I think taking on this class of challenge is very necessary to take us to the plateau of technology that is going to be very important to us.

Senator LOTT. That is good, and I understand it. Taking on the challenges are essential, and what it means for the future but, again—and I do not want us to play the space station off against other particular programs, but we have to put it in real-life terms.

We have to make it clear that there are benefits, significant benefits, not just dollar-wise or technology, but to everyday living, the everyday lives of our people. And what does it mean for a person that lives in New York City or rural Mississippi Delta that they can see and feel soon?

Mr. THOMPSON. Well, again, let me just draw your attention to the possibility of some pharmaceuticals that otherwise might not be available to you. I think an excellent story can be made about the manufacturing of some pharmaceuticals or particularly separating liquids in zero G which is a fundamental capability that is of benefit there.

I think understanding how to use the direct conversion of the sun to drive something of this size and utilize it probably not in the real near term but at some time in the future using the sun's energy without letting it grow green leaves and take several thousand years to become hydrocarbon might just be very beneficial to our society.

I think there are many potential benefits from the space station, and they run the full gauntlet from materials manufacturing to understanding energy conversion to understanding the life sciences processes.

For example, loss of bone calcium is something that we have to face and solve if we are going to live in zero G for long periods of time. If we can better understand the metabolism of bone calcium, who knows what benefits that will have for the aging in the future. So, those are things you can focus on.

Senator LOTT. Talk to me just a minute, any of you, and maybe Mr. Hallinan about the commercial applications and how they will work, what they will mean. Any of you with particular knowledge of commercial applications may respond.

Mr. HALLINAN. Senator, if I may respond to the prior question, the way you say uses, in my testimony that I submitted I listed many, many examples that we have got to date, and I guess I just wanted to mention when you go through the list, there are some things—these are very specific that I testified, but there is a trend that you can say that you are going to get direct benefits.

If I were going to talk to somebody in the Mississippi Delta that certainly there are benefits we are going to get in medicine, Bob Thompson was talking about certain aspects of it, but the list is full of direct applications to the medical benefits that you get.

There is also a substantial amount of information that comes from the programs on materials, specifically materials for clothing and advances that work their way into building and better construction and better material usage. So that comes out.

The next one that comes out is things of advances in computers, and that is something that is certainly competitive internationally and is very important and the space program probably has been at the forefront of computers, especially in the area of microminiaturization and the ideas where we are trying to reduce weight. And so I think that is an advantage.

The other thing I think was the fact that with TDRS in place, we will be doing a lot of communications and advanced communication, and that is very predictable. So, that is the one thing.

The other thing is, there are, I think, some mundane characteristics yet very beneficial in the fact that we are going to be in place to maintain all the space assets that we are launching. We are launching the great observatories, and we will be in a position to do maintenance on those. And so I think there is a predictable trend that we can get from looking at what we have done in the past.

Senator LOTT. Your list is very interesting and very good. I appreciate that.

Thank you, Mr. Chairman.

Senator GORE. Thank you, Senator Lott.

Let me just wrap up with a few short questions. The first of them, following on the questions of Senator Lott, I feel that too often we forget that our actions today impact the lives of others tomorrow, and I know I am personally concerned about the world of tomorrow and what my children and hopefully grandchildren someday will face. And I understand that your companies are even now interested in trying to reach out to the next generation of space explorers and engineers and scientists and technicians.

I wonder if you might mind briefly highlighting for the subcommittee some of the activities and programs and campaigns that your companies have initiated to attract our youth to science education and math in greater numbers. Mr. Winch?

Mr. WINCH. As noted in my testimony, we believe very heavily that Space Station Freedom is a contributor to the development of education of our youth. We participate quite a bit with the Alabama Space and Rocket Center. We provide personnel there at the center to brief the thousands of children who come in from all over the country, all over the world, in fact, to attend that center.

Senator GORE. You are talking about space camp?

Mr. WINCH. Space camp, right.

Senator GORE. In the center where they visit for shorter periods?

Mr. WINCH. Yes, but they attend there at space camp and learn the benefits of space and what is involved and come away with a great deal of enthusiasm. All of our people are quite enthusiastic about the opportunity to go over and speak to them.

We provide speakers around the country and civic clubs and schools and other types of facilities to encourage people to join in and learn about space, take courses and be involved in the future.

Senator GORE. Thank you. Mr. Thompson.

Mr. THOMPSON. Within McDonnell Douglas we have had for some time a project that we call Project Inform where we take some of our profit dollars and actually try to take the message of space and technology to the public and particularly to the school age public.

In addition, we established one of our working mock-up buildings relative to our site such that it would be convenient for school kids to come through as a trip stop as part of the Los Angeles school field-trip program. We have had tremendous response from students of all ages. It is one of the popular spots to visit as far as the school kids in the Los Angeles basin are concerned.

I think taking on these large complex programs and bringing to the minds of the young people how technology can focus and create something of this nature puts the excitement into technology that allows the bright kids that we are looking for to come into these specialties so that we can then have the specialists in the years ahead to keep this country as a leader in technology. And you have to have something that will turn on the kids, and I think these kinds of programs really turn them on.

Senator GORE. Dr. Greenwood?

Dr. GREENWOOD. Yes. General Electric, of course, has been very active in working with the educational system in the areas where we are located. We have provided speakers work with the schools, and have had an active summer program of involving students. We see a renewed interest and an active interest in the young people in space.

Senator GORE. Mr. Hallinan.

Mr. HALLINAN. We at Rockwell also have a broad scope program to involve youth, and there are a couple of things I would just like to mention because it is highlighted in my mind.

Number one, we supported NASA Lewis in a program that they ran with eight little elementary schools in Cleveland, Ohio, and it was a simulated shuttle mission. And I thought that was just really something. They involved each one of these schools completely, and each youngster in the school was involved, and they elected astronauts. And everybody in the school got an assignment, so that if you were an astronaut, that was one thing. But all the other youngsters got an assignment as well.

And they modified the school buses to be a space shuttle, and they had a launch and, of course, the astronauts had to stay in the school overnight. They were quarantined just like an astronaut, and they had a space breakfast the next morning, and these buses took off to the cheering youngsters at the school, and they went down the freeway in Cleveland, which I think was rather interesting.

Most of the shuttles from the schools you could identify, but some of them were polka-dotted in pink and things, and so you could see there was innovation. And then they convened at NASA Lewis and had a meeting and then they visited an alien planet, which happened to be another one of the schools. And on those buses the youngsters did various experiments. And we were in complete communication with their schools, and it was really something to see.

And, to me, the innovation and the imagination of those youngsters as to the type of experiments and their role in the program, and it was just a very wholesome thing to be involved with.

We also supported Congressman Stokes in concert with NASA Lewis in a space station poster contest, and it got a number of youngsters involved in that.

The other thing I will point out just as an item, there was recently on television a half hour space station Charlie Brown event, and I do not know about you, but Lucy has not always been my favorite, but Lucy just put out more good information about space stations, so Lucy right now happens to be one of my favorites, and I recommend that certainly if you are going to show that to children.

Senator GORE. We are glad to get that testimony, Mr. Hallinan, and your new feelings about Lucy.

Let me thank you. I did enjoy that. Two future capabilities that are of critical importance to future space activities are in-space servicing and in-space assembly of large structures. What experience does the space station program provide in these areas and what are the potential benefits of these capabilities in that regard? Is the space station the road to the future of these activities?

Mr. THOMPSON. Let me take the lead on that because the planning task to do the initial early assembly activities as it affects the central truss structure on space station are primarily focused in work package 2. And if you will permit me to go back a few years when we were first flying in earth orbit—particularly in the Gemini program, the first few times we went outside, we were not very successful because we did not quite understand the physics of the problem, we did not quite understand how to train the people properly. We did not anticipate all of the things that you need to be prepared to do, and so we did not do very well.

However, as we progressed and particularly as we learned how to train people, we learned how to think through the process. We learned how to put them in the proper work stations, give them the proper tools. I think as you saw in some of the recent shuttle missions, men can go out in that environment and if properly prepared can accomplish a very significant amount.

Now we have a lot of confidence. We spent a lot of time in our neutral buoyancy training facility and evaluation facilities. We have a lot of confidence that we will be able to go into space with a space station packaged in the payload bay of the shuttle and then unload this payload bay and assemble the structure you see in the model in front of you.

Some of the techniques that we are using just to assemble this particular facility are good precursors for assembling the accurate antennas that you may have to have for high gain antennas in space.

When I use the word versatile in the architectural approach here, as you well know in NASA's overall plans, there is a second phase in the space station program where an upper and lower truss structure is added to what you see on the table in front of you. To me the centralized truss is basically the land on which the space station operates, and we have the ability to build that truss structure out into whatever future directions and for whatever future type of work becomes appropriate around this facility.

And so I think that just taking on the job of building and operating the space station will then allow us to put in place the basic knowledge and the basic ability to go build the next generation of large structures even though you may have to have considerably more accuracy in the structure.

And so, again, the point I was trying to make by taking on this kind of a program, then you have the ability to take on a bigger, more complex program in the future.

Senator GORE. All right. Well, let me say that we will have other questions for the record for the first panel and if the NASA witnesses would be willing to respond in writing, we would appreciate it.

I would certainly like to express my thanks to all of the witnesses today. I think it has been a great hearing, and I have certainly learned a lot. I think the subcommittee has benefited greatly from your appearances here. The subcommittee stands adjourned.

[Whereupon, at 11:25 a.m., the subcommittee adjourned, subject to the call of the Chair.]

NASA AUTHORIZATION

TUESDAY, APRIL 4, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met at 9:30 a.m. in room SR-253, Russell Senate Office Building, Hon. Ernest F. Hollings (chairman of the committee) presiding.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The committee will come to order.

As you have probably heard, Senator Gore was to chair this hearing, but his son was involved in a very bad accident. We are glad this morning to hear he is conscious and holding his own. So Senator Gore is with his boy, and we have taken over because we have some witnesses who made the trip and we want to hear from them.

A wise man once said, "the tragedy of life doesn't lie in not reaching your goal. The tragedy lies in having no goal to reach. It is not a disgrace not to reach for the stars, but it is a disgrace to have no stars to reach for." [Benjamin Mays]

Today, we will review the fiscal year 1990 NASA budget request for NASA's Office of Aeronautics and Space Technology—the Office that turns dreams into realities, the Office that keeps our aerospace industry competitive in the markets of tomorrow, the Office that develops the technologies to enable us to fulfill our goals.

Over the course of the last few years, a significant effort has been made to expand the research and technology base of NASA; and the committee, therefore, is pleased to see another new technology initiative for the In-Space Experiments Technology Program incorporated in the fiscal year 1990 budget request. However, the Committee is concerned to see the budget request for two other technology programs—Pathfinder and the Civilian Space Technology Initiative—substantially below the fiscal 1989 runouts for the fiscal year 1990 budget. The Committee intends to explore these reductions this morning and to assess their impact on the core technology program. The Committee also intends to explore the concept of a set percentage of the NASA budget being earmarked for space research and technology to make sure the investments in tomorrow are not being sacrificed to the budget pressures of today.

Finally, the Committee intends to assess the fiscal year 1990 budget request for aeronautics, in particular for the new high speed commercial transport initiative. Aerospace is one of the few bright spots in our Nation's balance of trade, and the Committee wants to understand thoroughly NASA's efforts to capture the aerospace markets of tomorrow. The Committee also is interested in NASA's proposed plans to address the economic, environmental and technological challenges of high speed transports that will determine who will control these markets.

I am grateful that our distinguished witnesses have agreed to participate in a panel discussion of the high speed commercial transport initiative and to discuss its relationship to the National Aerospace Plane research and technology program.

I look forward to today's hearing and to the testimony of our distinguished witnesses.

Senator Kasten, do you have a statement?

OPENING STATEMENT BY SENATOR KASTEN

Senator **Kasten**. Thank you, Mr. Chairman. Our hearing today will be focusing attention on the high technology, and the development of future technologies, work of NASA. This work is critically important to maintaining the United States lead in the aerospace industry.

Both the aeronautical research and technology [R&T] program and the space R&T programs have budget increase requests to support their on-going work. In the case of the aeronautical R&T program there is also the $25 million new start for the high speed civil aircraft.

The technology development and assessment that we fund through these programs can be applied by the private sector to maintain our competitiveness in one area of trade where the United States still shows a surplus. Also, the Department of Defense benefits from NASA's work in order to preserve our aeronautical superiority in the national security area.

The benefits of NASA's research has always had applications beyond just the space and aeronautical fields. I can imagine that the work undertaken in the programs we are looking at today on materials and structures, propulsion and power, communications, and other areas will provide similar future benefits to society.

We will also be hearing about the national aerospace plane [NASP], which could have military reconnaisance and space shuttle-type applications, and the CRS study of commercial high speed aircraft. I look forward to the testimony of our witnesses. Thank you, Mr. Chairman.

The **Chairman**. Thank you Senator Kasten.

I have an opening statement that Senator Pressler would like to have included in the record.

[The statement follows:]

Opening Statement by Senator Pressler

Mr. Chairman, I would like to thank you for calling this hearing today. The research and technology programs at NASA are the key for future space missions. They provide the enabling technologies that allow us to undertake the challenging programs of the future.

Aeronautics technology is very important for the nation. The aerospace industry has been consistently our largest net exporting industry. We produce the finest aircraft in the world. Clearly, this is essential to our national security interests as well.

NASA and the Federal government have made important investments in aerospace technology. I believe that we must continue to make this investment.

The National Aerospace Plane (NASP) is a very exciting program. I am pleased to note that President Bush endorsed this program in a recent speech. The NASP will increase our access to space dramatically. The technologies that the NASP Government-Contractor team have developed already have advanced the state-of-the-art considerably. I recognize that this is a very ambitious program, but I believe that the potential payoff and the lessons we are learning along the way will justify this program. I would note also that the contractors involved in this program have invested sizeable sums of their own in this program.

Mr. Chairman, I thank you again for calling this important hearing. We must take great care to allocate efficiently the limited resources we have to invest in new technologies. National security and our competitive position require us to invest in the aeronautics arena. I look forward to hearing from our distinguished witnesses and I thank them for appearing today before the Subcommittee.

The **CHAIRMAN**. Dr. Ballhaus and Dr. Rosen, we have your full statements and your statements in their entirety will be included in the record.

If possible, I want to move on to this morning's second panel on high speed commercial aircraft because that is a very important discussion. Dr. Ballhaus, I do have a question for you, though.

Dr. Ballhaus, is America indeed the world leader in aviation?

STATEMENT OF WILLIAM BALLHAUS, DIRECTOR, AMES RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY DR. ROBERT ROSEN, ACTING ASSOCIATE ADMINISTRATOR FOR THE OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

Dr. **BALLHAUS**. Yes, Senator, I believe we are. But I also believe that we are being challenged as never before. We are an overall leader, but we have lost leadership in some areas.

The **CHAIRMAN**. And that therefore prompts the question, will we be the leader tomorrow? In other words, is the trend against us?

Dr. **BALLHAUS**. Senator, I do not think it is our birthright necessarily to be a leader. I think we have to continually earn that leadership, and that depends on a number of factors—our trade policy, economics. But it also depends very strongly on the investment we make in research and technology.

It is very clear that to remain a leader in the future we have to invest in research and technology to assure that we will have premier products available for the marketplace.

The **CHAIRMAN**. Well, are we making a sufficient investment to maintain our leadership?

Dr. **BALLHAUS**. That is a hard question, Senator. I think that we could certainly do more. However, I think the budget that we have requested is what you might call a marginal leadership budget. It is marginally adequate.

The **CHAIRMAN**. Well, what would be the adequate budget? That is really what I want to get to. We have become too accustomed now in this day because they say you do not need revenues. This really minimizes all the programs and in fact eliminates many of them. As you have characterized your program, it marginalizes others. When you say you have got marginal support here for research, please elaborate on that for me?

Dr. **BALLHAUS**. Senator, last year, in fact at the direction of this Committee in our authorization bill, we were asked to prepare a technology development and validation plan. We submitted that plan last year.

The plan lays out a number of opportunities to ensure leadership in civil aviation for the future. We have not been able to take advantage of as many of those opportunities as we would like, but we are moving out.

We do have some augmentations this year. We think that this year's budget is a step in the right direction. But in the future we are going to have to do more.

The CHAIRMAN. Well, you requested $512 million, I think, for fiscal year 1990 from OMB, not the $462 million approved for submission. Is $462 million now the request before the Committee?

Dr. BALLHAUS. That is correct, Senator.

The CHAIRMAN. What would be eliminated if we do not get the $512 million and you only get the $462 million OMB approved?

Dr. BALLHAUS. We have had several reductions during the process with OMB and also during NASA internal adjustments. We lost $10 million of the original request which would have been allocated to civil tiltrotor research.

There was a reduction of $18 million associated with a high speed computing initiative. That new initiative is basically on hold. We did get $2 million from OMB to start that activity, with an invitation to come back in the 1991 budget and to continue to pursue it.

And we lost $22 million in subsonic transport technology associated with ultra-high bypass propulsion, drag reduction, and fly by light.

The CHAIRMAN. Well, where does that currently leave us with respect to our foreign competition in microelectronics, superconductors, robotics, and the rest?

Dr. BALLHAUS. Well, Senator, as I mentioned before, we are being challenged across the board as never before. And in some of the areas that you mentioned, we are either tied for leadership or we have lost the leadership.

For example, in the area of superconductors we have leadership in some areas, but we probably have lost leadership in others. Like the thin film superconductors, the Japanese are leaders in that area.

In areas like materials, I think we have the lead in organic composites, but in ceramics we do not have the lead and in fiber technology we do not have the lead.

The CHAIRMAN. What about in space nuclear power and composite materials?

Dr. BALLHAUS. In space nuclear power, I think the Soviet Union has a clear lead. They have flown both thermionic and thermoelectric nuclear reactors.

The CHAIRMAN. The 1990 NASA authorization bill contains legislative language that would give NASA the authority to withhold or require the withholding from public disclosure certain technical data that are subject to the Export Control Act.

Briefly, we do not export the actual technology, but then we give the technical information to them under the Freedom of Information, as I understand it. So they just take it anyway and adapt it to their own needs. We basically cancel any good done by the Export

Control Act—if there is any—by our policy on Freedom of Information in this regard.

Am I right about that, and do you support this particular provision?

Dr. **Ballhaus**. Senator, I believe you are right and we do support it. We think it is important for NASA to be able to control certain technology dissemination.

[The statement and questions and answers follow:]

STATEMENT

of

Dr. William F. Ballhaus, Jr.
Director, Ames Research Center
and
Dr. Robert Rosen
Acting Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

I am pleased to present NASA's FY 1990 Aeronautics, Transatmospheric, and Space Research and Technology (R&T) budget requests which reflect a strong commitment to R&T and its importance to NASA's mission and United States competitiveness. Last year Congress declared in the NASA Authorization Act that preeminence in space and aeronautics is key to the national security and economic well-being of the United States. Investment in aeronautics and space R&T has played a fundamental role in achieving preeminence in the past and is the key to preeminence in the future. With the critical investment proposed in our FY 1990 budget request, we can look forward to a future of exciting possibilities in both aeronautics and space. For FY 1990, NASA is requesting $462.8 million for Aeronautics R&T, $127.0 million for Transatmospheric R&T, and $338.1 million for Space R&T as shown in the enclosed chart. I will briefly discuss the accomplishments and plans in each of these program areas.

Aeronautics:

NASA's Aeronautics Research and Technology budget request of $462.8 million for FY 1990 supports a program constructed to strengthen the United States leadership in aeronautics, by providing for a foundation of advanced technology upon which our industry can build to maintain our competitive posture in global aviation markets. Of the total Aeronautics request of $462.8 million, $335.7 million is for the R&T Base and $127.1 million is for Systems Technology.

The United States has long been the world leader in aviation. The aerospace industry is the leading exporter among all high-technology industries. Our aeronautical products continue to provide the largest positive contribution to our country's trade balance, and our military aircraft are superior in performance and reliability. But our leadership is being challenged today as never before.

Our dominance in important worldwide aviation markets is being challenged by escalating foreign competition. These competitors recognize the importance of advanced technology as a competitive factor and are committed to continuing the aggressive investments required to maintain their momentum in research and development.

NASA recognizes the serious effect that a loss of leadership in aeronautics could have on the economy and on the military strength of the United States. NASA, with its industry and university partners, has worked to provide technology which is instrumental in maintaining aeronautical preeminence. Through this close relationship with industry and the users of their products, we understand the technological advances required to keep the United States in front, and we have taken steps to reorient our program to keep abreast of changing times. However, there is much more that needs to be done to assure continued United States leadership in aeronautics.

National Goals: Technology has always been an important factor in aviation, but it is becoming even more critical as we push beyond the traditional frontiers of aviation. The NASA aeronautics research and technology program has been planned to respond forcefully to this growing international competition and to the goals contained in the "National Aeronautical R&D Goals" and the subsequent "Agenda for Achievement" published by the Office of Science and Technology Policy. These goals, in the hypersonic, supersonic cruise, and subsonic speed regimes, hold many technology challenges. Transatmospheric vehicles that will be able to cruise at hypersonic speeds and transition into Earth orbit will require new engines to propel them and entirely new materials and structures to withstand the intense heat. High-speed civil transports necessary to meet the burgeoning needs of long distance air travel will challenge our ability to integrate propulsion, aerodynamics, structures, and controls technologies into safe, efficient, environmentally acceptable, and affordable aircraft. Subsonic transports will have to be much more efficient, with revolutionary turboprops replacing the familiar turbine engines for many applications; with new levels of automation and control to enhance safety in the increasingly crowded skies; and with new types of shorthaul aircraft, such as a vertical lift tiltrotor capable of operating from city centers, needed to relieve the already overburdened airports. Military aircraft will have to operate from damaged runways and be capable of sustained supersonic speeds, yet be agile and maneuverable as no aircraft has ever been.

NASA Strategy: NASA has a leadership role to play in developing the technology base in the aeronautical disciplines necessary to meet these challenges. The NASA aeronautics program strategy is to emphasize emerging technologies offering the potential for major advances in aeronautics capabilities; to assure the health and productivity of our unique laboratories and national facilities; and to address critical barriers to the introduction of new aircraft concepts.

In line with our first strategy element, to emphasize high-payoff technologies, our FY 1989 program reflects increased emphasis on advanced propulsion concepts, advanced composite materials, and aviation safety and automation. Consistent with this strategy, our FY 1990 program will focus on research aimed at providing the technology for unprecedented levels of maneuverability and agility for next-generation military aircraft. This flight research will investigate the potential benefits of multi-axis thrust vectoring for high angle-of-attack maneuvering and flight.

Our second strategy element, assuring the health and productivity of NASA's key facilities, is addressed through the five-year NASA Major Wind Tunnel Revitalization program, which began in FY 1989.

In the third strategy element, critical barriers for new aircraft concepts are addressed and high-payoff technologies are targeted for development. A Civil Aeronautics Technology Development and Validation Plan was prepared by NASA in 1988 at the request of the Senate Committee on Commerce, Science, and Transportation. This plan defines advanced technologies for leadership in civil aviation. We have also defined those technologies which will maintain superiority in military aircraft.

With the help of the Federal Aviation Administration (FAA) and the Department of Defense (DOD) and, in cooperation with industry and the university community, NASA has formulated a comprehensive agenda that we are addressing methodically within necessary fiscal constraints. The FY 1990 budget request supports this agenda. It includes increased funding for research which will enable major enhancements in aircraft performance, improve our international competitive posture, and enhance our national defense.

FY 1990 Initiatives: One area that will be key to future competitive leadership is high-speed air transportation. International air travel has become an integral part of today's global marketplace. Nowhere is this more true than among the rapidly emerging economic powers of the Pacific rim. Long-haul transpacific travel is currently the fastest growing market and is expected to quadruple by the turn of the century. Because of this projected rapid growth and the extremely long flight times with subsonic aircraft, there will be an increasing need for future high-speed aircraft to provide more effective service. While subsonic transports will continue to be an important market segment, these high-speed aircraft will be the next plateau of competition in the international aviation arena. The competition for the high-speed market, which studies indicate may be able to support only one product, will be intense. The U.S. should be a key player in this critical segment of air transportation if we expect to retain a favorable trade balance and world leadership in aeronautics.

NASA-sponsored studies have indicated that, with sufficient technology development, these future high-speed aircraft could be economically competitive with long-haul subsonic aircraft. Currently, however, critical environmental concerns about atmospheric impact, airport noise, and sonic boom present powerful private sector disincentives. The FY 1990 NASA High-Speed Research program will address the resolution of these barrier environmental issues and develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental issues will place the U.S. in a position to make informed decisions on high-speed aircraft technology development in the future.

The program builds on NASA's extensive efforts in upper atmospheric research and previous experience in airport noise reduction technology and sonic boom reduction. The atmospheric research addressed in this program involves two elements: long-term atmospheric chemistry assessment and low-emission combustion research. The long-term atmospheric chemistry assessment will use sophisticated atmospheric particle transport models and complex atmospheric chemistry models to analyze the potential long-term effects of aircraft emissions on the stratosphere. In parallel with this effort, the low-emission combustion research will develop and test alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs which produce very low amounts of nitrogen oxide emissions.

The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression aimed at providing the same acoustic levels achieved by today's quietest subsonic aircraft. This research will expand on the results of previous acoustic fatigue testing, to include anechoic chamber tests of advanced technology jet noise suppressor designs. Airport noise calculations will examine projected levels for alternative aircraft and engine systems.

The third element of the program, sonic boom reduction, includes aircraft configuration research aimed at reducing the sonic boom levels, combined with human response evaluations to define the criteria for acceptability. Aircraft configuration research will focus on design analyses and wind tunnel testing of low sonic boom configurations as well as analysis and experimental research on supersonic laminar flow control. Selected flight research efforts will be conducted to verify the analyses and wind tunnel test results. The F-16XL aircraft was recently obtained from the Air Force and will be used as a flying testbed to investigate the feasibility of applying laminar flow control techniques developed for subsonic transports to supersonic flight with delta wing aircraft.

NASA and the DOD have traditionally cooperated to provide technology options to allow superior military aircraft. The NASA research in high angle-of-attack aerodynamics has shown that it may be possible to greatly expand the flight envelope of future fighter aircraft with substantial increases in military effectiveness. The military is seeking to exploit these lower-speed, high angle-of-attack portions of the flight envelope to achieve tactical advantages through increased agility and maneuverability. We will investigate this regime from a flight science perspective, achieving an understanding of the physics and validating our design tools. To date, experiments in NASA wind tunnels have demonstrated the capability to achieve post-stall maneuvering at angles of attack approaching 90 degrees. Our computational codes are being developed to predict these highly nonlinear flow conditions. The F-18 High Angle of Attack Research Vehicle (HARV) is generating flight data to validate our results through angles of attack up to 30 degrees. Our requested augmentation will expand the flight validation to extremely high angles of attack approaching 90 degrees. This will be accomplished through modification of the HARV with a thrust vectoring control system to allow sustained operations at extremely high angles of attack. This will permit thrust vectoring beyond stall as well as evaluation of advanced maneuver management concepts. The resulting predictive codes and design methodologies will enable DOD to have the option of incorporating this high-payoff technology into the design of future military aircraft. The potential advantages of a future military fighter with an ability to fully exploit the flight envelope include increased mission effectiveness as well as enhanced safety.

Major Accomplishments: We have enhanced the productivity of the Nation's leading computational capability by greatly increasing the computing power of the Numerical Aerodynamic Simulator (NAS) at the Ames Research Center. A second high-speed processor, the first delivered Cray Y-MP, was integrated into the NAS and is presently operating in a pathfinding role. The NAS has been used in a wide range of aeronautical disciplines including high angle-of-attack aerodynamics, internal computational fluid mechanics, rotorcraft and powered lift modeling, and National Aero-Space Plane support. During the last year over 1,150 researchers, working on 350 projects, accessed the NAS from 110 remote sites.

As part of our work in computer science, alternative architectures such as massively parallel processors are being investigated for possible application to aeronautical problems. This work will be expanded as we seek to develop the computing power to allow new and innovative approaches to solving complex multidisciplinary problems and integrating individual computational tools into total system solutions. We are actively working with the other members of the government High-Performance Computing team to define NASA's role in this critical multi-agency national program.

The safety and efficiency of the Nation's air transportation system has come under increasing scrutiny in the recent past. This national need has sparked a renewal of cooperation between NASA and the FAA in those areas where our mutual interests and expertise overlap. New agreements on wind shear/adverse weather and tiltrotor certification have been negotiated, and we are actively cooperating with the FAA in the areas of aging aircraft and human factors. The Aviation Safety and Automation Research program augmented in FY 1989 is off to a good start and has been coordinated with FAA and industry efforts in the areas of air traffic control and human factors. One recently developed concept, the takeoff performance monitor system, has the potential for increasing pilot awareness and enhancing flight safety. This system allows a pilot to monitor a single display, rather than multiple gauges, to determine whether to continue a takeoff or abort. Flight validation by NASA research pilots and evaluation by line pilots from major airlines have proven the concept to be viable and the research results are being transferred to industry. Flight in adverse weather is known to present dangers, but the actual effect of heavy rain on the aerodynamic performance of an airplane's wing has not been well understood. With the recent activation of a heavy rain test facility at the Langley Research Center, previous small-scale test results can be validated in large scale. This improved understanding of the effects of heavy rain, when combined with the results of flight evaluations of advanced adverse weather detection equipment, will result in safer and more efficient air transportation.

Basic research in subsonic aerodynamics continues to produce promising results. Wind tunnel tests have shown that wings with a crescent planform have a 3 - 4 percent reduction in induced drag when compared to an elliptical wing, which was previously thought to be the theoretical optimum. This improvement in drag is accompanied by enhanced aerodynamic performance near stall. This research could lead to a low-speed wing planform designed for safer and more efficient general aviation airplanes.

Rotorcraft and powered lift research continues to advance as an important segment of the NASA aeronautics program. The recently upgraded National Full-Scale Aerodynamics Complex (NFAC), which became operational last year, is a key facility for rotorcraft and powered lift research and for supporting major DOD systems development. Rotor performance predictions were recently validated in the 40-foot by 80-foot wind tunnel section of the NFAC in support of DOD's V-22 tiltrotor development. We are also analyzing the complex flow fields about powered lift vehicles in ground effect using advanced computational fluid dynamics techniques. Initial comparisons of experimental and computational results have been very promising, and the capability of these computational techniques is being expanded to include improved turbulence modeling and rate-of-descent effects. Integrated flight and propulsive controls, as well as ejector performance, are being evaluated in full scale and at operating temperatures using the E–7 model. The results of these tests will be used to validate small-scale, cold-air tests and further refine our design and analysis techniques.

Composite materials are being used more often in current and future airframe designs because they are lighter and stiffer than conventional metallic aircraft structures. A new thermoplastic material, LARC TPI, developed by the Langley Research Center, is currently being evaluated by the aircraft industry. Combined with innovative manufacturing techniques, such as thermoforming, this material offers the potential for improved aircraft performance with reduced production costs. Our research in advanced composite materials, which was augmented last year, has been well coordinated with industry and universities. The focus is on advanced materials, such as toughened thermosets and high-temperature thermoplastics, and the innovative design methods to optimize the use of these materials in aircraft structures. Our research goal is to develop composites technology for primary airframe structures which will result in a 40 percent reduction in airframe weight and a 25 percent reduction in acquisition cost. This will provide airframes which can be constructed inexpensively and operated efficiently.

High-temperature materials for application to future engines and hypersonic airframes require strength and durability that is not obtainable today. Material systems, such as advanced intermetallics, that have good high-temperature capabilities often lack the strength for engine or airframe applications. Recent experiments have shown that alloy modifications using minute quantities of additives can significantly increase the room temperature ductility of intermetallics, enabling their use in airframe as well as engine applications. This has the potential to double the life of high-temperature components while providing a 30 percent reduction in weight.

Improvements in propulsion technology have historically provided a major share of aircraft system performance improvements, enabling the development of new generations of aircraft and flight vehicles. Understanding of the complex flows inside an engine is the key to achieving further advances in propulsion technology. The remarkable advances that have been made in computational fluid dynamics are being applied to develop an understanding of flows in engines. Previously developed codes model the flow through a single stage of turbomachinery with various levels of complexity. A new approach is now under development that will analyze the highly complex vortical flow structures that occur in multiple stages of turbomachinery using existing supercomputers. The initial version of an expert system was demonstrated that provides a user-friendly interface to make these codes more easily available to a wider range of researchers and potential users.

Another recent accomplishment is an outstanding example of how we successfully apply our strategy. In 1988 a NASA/Industry team was awarded the Collier Trophy, the most coveted award in Aeronautics research and development, for "developing advanced turboprop propulsion technology for new fuel efficient subsonic aircraft propulsion systems." The high-speed turboprop, an advanced technology reincarnation of the propeller, has proven to be substantially more efficient than the jet engine for airliner operations. This spectacular accomplishment, led by the Lewis Research Center, began in the late 1970's with a few good ideas to save fuel. Analyses and systems studies were followed by small-scale model and component testing in NASA and industry facilities. Predictive computer codes were refined and validated. This experimental and analytical base provided the ATP team the confidence to design, build, and flight test large-scale hardware. This story exemplifies the way our research program develops and validates new technologies that can be incorporated in future aviation products.

Transatmospheric Research and Technology:

The National Aero-Space Plane (NASP) program continues to make excellent progress toward its key milestone -- the decision to build and test the X-30 flight research vehicle -- now scheduled for September 1990. FY 1990 will feature extensive testing of engine modules and airframe structural components and acceleration of efforts in government and industry to reduce the risk in the critical technologies required to build the X-30. Enthusiasm is high throughout industry, NASA and other government laboratories, and universities. The commitment of the NASP engine and airframe contractors is significant, and they have demonstrated this by contributing almost one-third of the total dollars in the current technology development phase. The overall national team includes over 5,000 people and involves some 200 companies in 40 states.

NASA's strong support for NASP is a direct reflection of the many benefits we expect the program to produce. First and foremost among these is the capability to provide improved manned access to earth orbit. An airbreathing vehicle based on NASP technologies holds the potential to provide flexible, relatively lower cost and rapid access and would greatly enhance our overall space transportation infrastructure. Second, the exciting technologies which are being made available by the program will have a far-reaching impact in many other NASA programs. Our partnership with the DOD in experimental aircraft design and flight testing is built on a long history of successful joint programs and is in the spirit of NASA's charter role in aeronautics.

The total NASA budget request for NASP in FY 1990 includes $127M in Transatmospheric R&T, an increase of $38M from the total NASA share in FY 1989. This represents the planned growth agreed to in the revised Memorandum of Understanding (MOU) between NASA and the DOD and is needed to support the engine and airframe component testing in preparation for the X-30 decision. In addition to direct funding to the program, NASA also provides significant support in terms of technical staff and facility operations. More than 300 of our top in-house technical staff play key roles in the management of the program, in conducting research to mature key NASP technologies, and in providing technical support to the engine and airframe contractors. We are also providing a broad array of unique computational and experimental facilities to support the program.

There is a strong and dedicated management team in place to lead this joint national program. The team is led by the NASP Steering Group, headed by the chairman, the Under Secretary of Defense for Acquisition and the vice-chairman, the NASA Associate Administrator of the Office of Aeronautics and Space Technology (OAST). Overall program management is provided by the Air Force Under Secretary for Acquisition. The Program Executive Officer is the Commander of the Air Force System Command and reporting to him is the Manager of the Joint Program Office (JPO) at Wright Patterson Air Force Base, who provides day-to-day program management. In addition, there is the newly-established NASP Inter-Agency Office (NIO) in the Pentagon, here in Washington, D.C. The principal deputies in both the JPO and NIO are NASA employees. NASA has an office in OAST to oversee our participation in the program.

The three major elements of the NASP program are the engine contracts, the airframe contracts, and the technology maturation effort. It is in the technology maturation area that the government laboratories, particularly the NASA Research Centers, have major activities. The purpose of this work is to improve the state of critical technologies to reduce the risk in developing the X-30. Throughout this past year the technology maturation effort has made important contributions in the areas of propulsion, computational fluid dynamics, aerothermodynamics, advanced materials, and flight research planning.

In the propulsion area, research at the Langley Research Center has provided improved understanding of the physical processes in the inlet, combustion chamber and nozzle of the scramjet engine, which is required for propelling the

X-30 from Mach 4 to near-orbital speed. At the Lewis Research Center, tests have been completed on a large-scale inlet model and efforts continue on evaluating the potential of slush hydrogen as an X-30 fuel. Advanced computational fluid dynamics (CFD) codes, developed at NASA Ames and NASA Langley, which accurately predict aerodynamics and physical flow effects at hypersonic flight conditions, have been released to the NASP contractors for use in their engine and configuration development. Tests in the unique NASA Langley quiet tunnel have verified methods for predicting the onset of boundary layer transition at Mach numbers up to 3.5. This information and the results of ongoing research applicable at higher Mach numbers are essential to achieving the desired aerodynamic and thermal performance of NASP and other hypersonic vehicles.

Excellent progress is being made in the critical area of advanced materials and structures. NASA investigators are conducting important research in characterizing candidate materials such as metal matrix composites, carbon-carbon, and ceramics and are evaluating carbon-carbon coatings needed for survival of some of the materials in the severe X-30 flight environment. Centerpiece of the overall materials and structures effort is the unique consortium of the five NASP engine and airframe contractors who are working closely to accelerate the development of the needed materials. A second consortium of this type is being established for the cooperative development of X-30 subsystems.

Flight research and test planning is continuing, utilizing simulations of NASP vehicles with predicted performance based on CFD results from the Numerical Aerodynamic Simulator (NAS) and data from tests in NASA wind tunnels. Approaches to the expansion of the X-30 flight envelope, cockpit displays, off-design operation of systems, and other facets of flight test are being evaluated by simulation techniques to establish a safe means to conduct the flight program and to ensure that the critical aerodynamic, propulsion, structures, and systems data will be acquired. The NASP simulator at Ames-Dryden will be moved in FY 1990 to the new Integrated Test Facility (ITF) to carry out more detailed planning and simulation of normal and emergency procedures. This will ensure a safe and productive flight program and will support the technology readiness assessments in 1990.

Wind tunnels, large computer systems, and other unique test facilities at the NASA Research Centers and other government and industrial laboratories are being used to support both the contractor and technology maturation efforts. Rocketdyne has conducted successful tests of a one-seventh scale model of their engine in the Langley Research Center's scramjet facility. General Dynamics and Rockwell conducted tests at the Naval Weapons Systems Command to verify the performance of their inlet design. These tests, the direct connect combustor tests by Pratt & Whitney at Marquardt, and results from other engine test facilities provided by the NASP program, have increased confidence in the scramjet engine concepts. Data from wind tunnel tests have also provided calibration of advanced CFD codes for use by the engine and airframe contractors. McDonnell-Douglas has evaluated candidate structural configurations under thermal loads using test facilities at NASA Ames-Dryden. Rockwell has conducted aerodynamic tests to determine stability derivative effects on their configuration in their own Trisonic Tunnel and at the Arnold Engineering Development Center.

NASA has committed time on the powerful Class VI computers at each of the Research Centers to support NASP analyses and design activities. NASA personnel supporting this program used this capability in the downselect of contractors in 1987, and it will support the engine Test Module Review (TMR) in April 1989. These large computer systems, along with those of the contractors, have been linked by satellite to the NAS at the Ames Research Center to give the program ready access to the world's most powerful aerodynamic computer system. Almost 30 percent of the available NAS capability over the past three years has been used by the NASP program. The excellent technical progress to date in the NASP program would not have been possible without this powerful supercomputer capability.

In the face of emerging hypersonic vehicle programs in Europe and Japan, the United States continues as the leader in hypersonic research and is uniquely positioned to exploit advances in propulsion, materials and structures, computational sciences, and controls technologies for future aerospace vehicle applications. The NASP program is the focus for our national effort and NASA is proud to be a partner with the DOD and to commit our technical expertise, management skills, and unique national facilities toward the success of this effort.

Space Research and Technology:

The basic goal of NASA's Space R&T program is to enable and enhance future potential civil space missions by providing a solid base of technical capabilities and talent. Our request this year reflects our commitment to continue our progress toward that goal, expanding the frontiers of technology to enrich our Nation and capture the benefits of space for future generations.

Advanced technology has played a major role in the past successes of the civil space program and is the foundation for success in undertaking potential future missions to serve the Nation's goals in space. Adequate investment in such technology lowers the cost, the risk, and the development lead time associated with our activities in space. New technology is the key to the future; without it, we are locked in the present.

The importance of space technology to the Nation, however, goes far beyond NASA's next program or mission. The development of these advanced technologies enhances the economic competitiveness of our aerospace and related industries, contributes to the national security, and serves as a stimulus to the education of new generations of scientists and engineers.

Unfortunately, over the years the Nation's space technology capabilities have not kept pace with the Nation's space technology needs. After peaking in the early 1960's, NASA's investment in Space R&T declined, in terms of constant purchasing power, to less than 20 percent of what it had been at the height of the

Apollo era. As a result, many programs became limited by a lack of technology options, particularly with respect to validated, or user-ready, advanced technologies.

At the same time, many other most capable and farsighted countries were laying plans for aggressively targeting aerospace and related high-technology industries as strategic thrusts for the twenty-first century. Those technology development efforts have already begun to pay off in the form of significantly enhanced space capabilities -- for France in expendable launch vehicles and earth observing systems, for Canada in space-qualified robotics, and for the Soviet Union in planetary exploration, heavy-lift launch vehicles, and an evolving, permanently inhabited space station. As summarized by the National Academy of Sciences, the result of this imbalance in investment was that "the United States is losing its competitive lead in space, and new technology is unavailable to offer the nation a selection of future options in space."

Within the past few years, however, there has been widespread recognition and support -- in Congress, in the Administration, and elsewhere -- of the need to revitalize our national space technology capabilities. In response to this need to invest in our Nation's future in space, and in response to the broader need to strengthen the capabilities and talents for supporting all national space sectors, civil, national security and commercial, NASA developed a balanced strategy for the conduct of its Space R&T program; namely:

- Maintain a strong and innovative R&T Base program: research into basic long-term, high-payoff space technologies
- Revitalize the Nation's technology for applications in Earth orbit through the Civil Space Technology Initiative
- Initiate the Pathfinder program to develop the enabling technologies for the potential, future exploration, both human and robotic, of the solar system
- Extend the Nation's space technology development activities to experiments in space
- Broaden the participation of the nation's universities in the conduct of Space R&T
- Focus ongoing R&T base activities, as needed, to enable the initiation of new technology programs to serve appropriate national needs.

With the support of the Administration and this Committee, NASA has begun to implement this strategy. In FY 1988, the funding of the Civil Space Technology Initiative (CSTI) signaled the beginning of the revitalization of the United States space technology capabilities. And, in FY 1989, we began to lay the foundation for future expansion of human presence and activity beyond Earth orbit into the solar system with the initiation of the Pathfinder program.

NASA's FY 1990 Space R&T budget request represents a balanced and responsible continuation of that overall strategy. Of the total request of $338.1 million, $130.1 million is for basic disciplinary research in aerothermodynamics, materials and structures, power and propulsion, and other key space technology fields; included in that total is support for the recently-initiated University Space Engineering Research Center program. In addition, $144.5 million is requested for CSTI to continue the long-needed, systematic revitalization of the United States space technology capabilities and $47.3 million for the Pathfinder program to investigate the long lead-time technologies that will be required for all potential future exploration missions. Finally, we are requesting $16.2 million to initiate an In-Space Experiments Technology Program to begin working toward the appropriate balance between ground-based and in-space research and technology development.

To repeat, our strategy is balanced and responsive to a range of important national priorities. Our FY 1990 budget request continues the implementation of this strategy and represents the investment necessary to maintain movement toward our future space goals.

Civil Space Technology Initiative: The Civil Space Technology Initiative (CSTI) was the first of NASA's new focused technology programs (in contrast to the fundamental disciplinary research conducted as part of ongoing R&T base activities). CSTI was designed specifically to: (1) fill the gaps in the agency's basic technical capabilities that had resulted from too many years of reliance on Apollo-era technologies and (2) advance critical technologies to the point of user-readiness for safe incorporation into relatively near-term, high priority NASA missions.

The CSTI program has already begun to produce significant accomplishments in key focused technologies, including automation and robotics, space power, and information technology. These and other technologies will be utilized in the systems of the 1990's to provide cost-effective and reliable access to, operations in, and science missions from Earth orbit.

As a focused program, CSTI is different from the traditional Space R&T program. As mentioned above, CSTI was intended to take technologies beyond the basic research stage to demonstrate the benefits and reduce the risks associated with specific advanced technologies. Also, the elements of CSTI were designed to result in deliverables, ranging from ground-demonstrated propulsion and structures hardware to data acquisition and processing techniques.

CSTI is characterized by large-scale hardware and by commitments, milestones, and delivery dates. Certain levels of investment are therefore necessary for the successful realization of the CSTI effort. The FY 1990 budget request of $144.5 million represents the amount of investment necessary to maintain the character of the CSTI effort. The implications of a smaller investment are clear from last year's experience: significant and costly replanning efforts; the "stretchout", reduction, and rescoping of contracts; slippages in technology milestones of up to

18 months; and, equally important, a real reduction in the enthusiasm and excitement that have been clearly evident in the scientists and engineers engaged in this critical work.

Pathfinder: Pathfinder, initiated in FY 1989, consists of a group of research efforts addressing surface exploration, in-space operations, humans in space, and space transfer. The technologies developed in these areas will be the key to making decisions on all potential future solar system exploration.

Pathfinder is, at this point, in a startup phase. Activities have been started across a range of important technologies, with multi-Center teams being put into place and some procurements initiated. Many elements have been reduced in scope, however, and others -- such as research in photonics, cargo vehicle propulsion, and resource processing pilot plants -- have been deferred as a result of reduced funding.

Pathfinder remains an essential part of the National Space Policy and of the NASA Program, but we reluctantly limited its budget growth for FY 1990. This request reflects the need to balance a range of national needs in a tight fiscal environment. Although Pathfinder has been slowed from our initial expectations, a viable startup program can be maintained through FY 1990.

In-Space Experiments Technology Program: The effort to revitalize our Nation's space technology (as begun by CSTI) has been focused on ground-based research and development. Our space missions also require technology for operations in space. In many instances, it is essential that the development of that technology be conducted in the actual space environment. To round out the strategy for the revitalization of our technical capability, we need to establish a proper balance between ground-based and in-space research.

The In-Space Experiments Technology program will develop flight experiments to test highly innovative technologies, identified through ground-based research, that require research, testing and validation in the space environment in order to understand basic phenomena, reduce risk to potential users, and increase the rate of technology transfer to future space missions. Among the areas requiring in-space experimentation are fluid behavior in microgravity environments (critical to the design of advanced thermal management, power, propulsion, and life support systems); the use of robotics in space construction, servicing, and other in-space operations; and environmental effects on materials from long-term exposure to the space environment. One example of the benefits of this work can readily be seen from the proposed arcjet experiment, which will lead to the development of an advanced rocket motor for station keeping that will enable communications satellites to remain on orbit for longer periods of time, greatly increasing the useful life of the spacecraft.

In addition, in response to recommendations from NASA's advisory groups that we provide opportunities for the private sector and university space engineering communities to conduct in-space experiments, we have made an industry/ university outreach program an integral part of the In-Space Experiments effort. To date, we have selected five industry and university proposals for development and flight validation. Typical of these is the tank pressure control experiment which will validate the mixing and stratification characteristics of fluids in a zero-gravity environment. Data collected during the experiment will contribute to reducing the cost and complexity of fluid tanks in future spacecraft.

The FY 1990 budget request of $16.2 million will fund development and flight validation activities for both selected in-house and industry and university experiments. With this augmentation, new in-space experiment development activities will be funded under the In-Space Experiments program. Work to define future experiments will be funded, as is appropriate, in the Base itself. (For example, another thirty-six Outreach proposals for future in-space experiments have been selected for further definition as part of an ongoing R&T Base activity.) Finally, although these experiments are designed to be conducted primarily onboard the Shuttle and ELV's, many of them will serve as precursors to experiments that will use Space Station Freedom's unique facilities as they become available later in the next decade.

Again, the decision to request funding for this program is not one that was made lightly. It is important to restate, however, that the overall strategy of the Space R&T program is one that calls for a vigorous revitalization of the Nation's space technology. The successful implementation of that strategy requires that NASA pursue a balanced program, addressing both ground-based and in-space R&T.

National Capability: The Nation's future in space, of course, depends on more than just the development and testing of technologies themselves. Our future depends upon the continued availability of qualified scientists, engineers, and managers who are able to conduct and administer programs to expand our national competence in space technology. Broadening NASA's partnership with universities continues to be an integral part of the Space R&T program. For example, the In-Space Experiments Technology program will provide opportunities for developing technical strengths in the engineering disciplines within NASA, industry, and academia alike.

The recently-initiated University Space Engineering Research Center (USERC) program is another key element in this NASA/university partnership. These Centers, important catalysts that bring together people, knowledge, and methodologies, conduct focused research in one or more of the traditional space engineering disciplines, and in cross-discipline combinations, to develop advanced techniques, tools and technologies for future space systems. NASA monitoring teams for each university Center ensure the timely flow of information and technology between the Centers and NASA programs and foster collaborative arrangements between Centers. The USERC program stimulates engineering curricula and increases the availability of qualified space engineers by making a long-term commitment to universities.

A key aspect of this program is the independence with which each Center will be operating. In contrast to some other types of university involvement where the academic institution primarily conducts research in a very narrow area, under the USERC program each Center will be able to identify and pursue its own avenues of inquiry within a broad charter. This freedom and flexibility will encourage innovation on the part of students and faculty alike, and result in valuable new contributions to the Nation's civil space technology effort.

The first USERC solicitation occurred in August 1987. Over one hundred institutions responded to that first solicitation with outstanding proposals -- and with extreme enthusiasm. Nine were selected as follows:

- University of Idaho: VLSI Hardware Acceleration Center for Space Research
- University of Arizona: Center for the Utilization of Local Planetary Resources
- Rensselaer Polytechnic Institute: Intelligent Robotic Systems for Space Exploration
- North Carolina State University and North Carolina A&T University: Mars Mission Research Center
- University of Cincinnati: Health Monitoring Technology Center for Space Propulsion Systems
- University of Michigan: Center for Near-Millimeter Wave Communication and Sensing Technology
- Massachusetts Institute of Technology: Controlled Structures Technology
- University of Colorado: Center for Space Construction
- Pennsylvania State University: Center for Space Propulsion Engineering

Educators continue to praise the USERC program. One called it "one of the most creative and innovative university programs"; another said that it was "one of the most significant developments in the history of the university." The first comprehensive review of this program was held this past January and confirmed the value of the program to both NASA and the academic community.

NASA Capability:

A successful NASA program depends critically on the capability of its staff. You have heard Dr. Fletcher, and you will hear others, testify on the need for maintaining the continued health and strength of NASA's institution, particularly its people and its unique research facilities. Perhaps nowhere is this need more vitally felt than with regard to the Aeronautics and Space R&T program. As we work to maintain our traditional leadership in aeronautics and to revitalize the Nation's space technology, we must remember that people are the core of our capability. The increased emphasis on technology development and validation needs to be matched with a corresponding long-term investment in human resources. To do otherwise would be to provide only half of a solution.

Similarly, we must continue to make available to these researchers, and to other appropriate users, the state-of-the-art facilities required to support advances in critical aerospace technologies. In FY 1989, NASA initiated a comprehensive five-year Wind Tunnel Revitalization program to upgrade the condition of the NASA wind tunnels critical to aeronautical research and U.S. developmental programs. Many of these facilities are unique national resources; all of these facilities contribute to the successful attainment of the Nation's goals in aeronautics and space.

In short, program strength comes from, and requires, outstanding people and facilities as well as adequate program funds. We urge you to support the revitalization and invigoration of NASA's workforce and facilities as represented in the agency's Research and Program Management (R&PM) and Construction of Facilities (CofF) budget requests. Such support is central to the continued success of the United States Aeronautics and Space R&T program.

An Investment in the Future:

NASA is proud of the role aeronautics and space technology have played in advancing the technological capability of the United States. Continued leadership is crucial to the economic well-being and security of our Nation. However, technological leadership is not an American birthright, we must continually earn it. Today, we are challenged by unprecedented levels of foreign competition as many nations increase their investment in aeronautics and space technology. Our FY 1990 budget request is balanced and fiscally realistic and is based on a strategy that will contribute significantly to enhancing our Nation's economic and political prestige through scientific and technological leadership in aeronautics and space.

Leadership in aeronautics is crucial to our international balance of trade and national security and to the safety and efficiency of our air transportation infrastructure. We have a NASA strategy for maintaining technology leadership and, while we have made substantial progress in the past, much remains to be done. In partnership with U.S. industry, other government agencies, and the university community, we have prepared a roadmap and defined priorities to conduct pioneering research in emerging technologies, selectively conduct the highest payoff systems technology programs, and produce technologies that industry can incorporate in future products. In FY 1990, we must maintain the integrity of our Wind Tunnel Revitalization plan, aggressively pursue those barrier technology issues that will allow U.S. industry to make informed decisions on high-speed aircraft, and provide the technology options to fully exploit the flight envelope of fighter aircraft.

Similarly, we have made great strides in space technology but we cannot afford to lose any momentum at this time if we as a nation hope to maintain our future in space. It is important to keep in mind that the Space R&T Base, CSTI, Pathfinder and the In-Space Experiments Initiative, are important not just to NASA but to the Nation's future capabilities in space as well. Dr. Fletcher has cautioned that "long-term investments are always an easier political target than are deliveries of current services." As in most cases, the easy path is not necessarily the right path. Postponing advanced research has an effect just as real, an impact at least as great, as missing a flight opportunity or any other near-term milestone. The only difference is that the impact may not be apparent for years to come -- and by then it is too late to correct.

The FY 1990 budget represents a balanced program that will support research and technology instrumental to maintaining the United States preeminence in aeronautics, continue the revitalization of our Nation's space technology capabilities, and demonstrate achievements toward the decision to build and test the National Aero-Space Plane. The question is not whether we can afford to take on these challenges but whether we can afford not to. With this critical investment in technology, as reflected in our budget request, we can look forward to a future of exciting possibilities in both aeronautics and space. We are asking you today to support our effort, to continue this critical investment in our technology foundation to keep the Nation's civil aeronautics program preeminent and our space program on track. With your support, we can expand the frontiers of the future for the benefit of all Americans.

Thank you, Mr. Chairman. That completes my prepared testimony. I would be happy to answer questions.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY
(R&D dollars in million)

	FY 1988	FY 1989	FY 1990
AERONAUTICS R&T	332.9	404.2	462.8
R&T BASE	257.2	315.6	335.7
SYSTEMS TECHNOLOGY	75.7	88.6	127.1
TRANSATMOSPHERIC R&T	52.5	69.4	127.0
SPACE R&T	221.3	295.9	338.1
R&T BASE	107.1	134.1	130.1
CSTI PROGRAM	114.2	121.8	144.5
PATHFINDER PROGRAM	-	40.0	47.3
IN-SPACE TECH. EXP'TS	-	-	16.2

Responses to written questions submitted by Chrm. Gore.

Environmental Issues

Question 1: Do we have sufficient understanding of the impact of the operation of a fleet of high speed commercial aircraft on the environment (ozone, sonic boom, low-altitude noise, etc.) to:

a. decide whether to go ahead with either an R&TD program or commercial development for a high speed commercial aircraft, or

b. know how to design the airplane, or how to manage its operations, so as to reduce the impacts to acceptable levels?

Answer 1a: At this time, the answer is "no" with respect to initiating a comprehensive R&TD program or commercial development. Based on the results of our studies to date, conducting research to address the environmental concerns is top priority and this is the basis for our FY 1990 request. We have sufficient understanding of these environmental concerns to initiate the proposed research program focused on the technology required to address these concerns. Obtaining clear progress in resolving these critical environmental issues is required in order to place the U.S. in a position to make informed future decisions on initiating a comprehensive R&TD program to provide the technology required for future commercial development. At this time we consider it unwise to initiate a comprehensive R&TD program without a clear understanding that these environmental issues can be resolved.

b: No. Adequate resolution of these concerns requires conducting the proposed High-Speed Research program.

Question 2: Is the proposed NASA initiative structured properly to address these issues and to validate the technology advances required?

Answer 2: Yes. The specific purpose of the proposed High-Speed Research program is to address these issues. By design, it is structured to provide the necessary research and technology basis, including small scale technology verification, to address the environmental issues.

Question 3: What federal agency should have the lead responsibility for interpreting research on the environmental impact of high speed aircraft?

Answer 3: At this point in the program, NASA is the appropriate federal agency to lead the research and technology efforts. These efforts are being guided and reviewed by an Atmospheric Advisory Committee, made up of some of the world's leading atmospheric scientists and chaired by Dr. Robert T. Watson, Chief, Upper Atmosphere/Research/Tropospheric Chemistry Branch, NASA Office of Space Science and Applications. As these efforts mature, increased coordination and involvement with other federal agencies, such as the FAA, will be required, and the FAA will develop any necessary certification standards.

Question 4: What assumptions do proponents of the program make regarding more stringent environmental standards in the future than those that exist today? Will the proposed aircraft be able to meet these standards?

Answer 4: At this point it is assumed that a future high-speed civil transport would have to meet the same noise requirements imposed by FAR 36 - Stage 3 on subsonic civil transports and the continuation of the current prohibition against commercial supersonic flight over land. In addition, although there are no atmospheric protection standards in existence today, it is assumed that any future high-speed civil transport will have to meet such standards if they were to be developed. The proposed High-Speed Research program will provide the necessary information to evaluate the ability to meet future environmental standards.

Question 5: Is there any way we can be certain of the environmental consequences of a high speed commercial aircraft short of undertaking the proposed technology initiative being proposed by NASA?

Answer 5: In our estimation, no. The environmental issues are very complex and the proposed High-Speed Research program is required in order to provide an adequate knowledge base for evaluating these issues.

Question 6: To what extent will the flight regime, in particular the cruise altitude of the aircraft, affect the overall level of ozone depletion?

Answer 6: At the present time, preliminary assessments using current two-dimensional atmospheric models have indicated a strong sensitivity to cruise altitude. In the troposphere, extending from the Earth's surface up to about 7 - 10 miles (depending on latitude, season and weather), the temperature generally decreases rapidly with altitude, clouds form, and convection is active. Above the troposphere, in the stratosphere, the temperature changes very little with altitude, clouds and water are rare, and there is practically no deep convection. Therefore, emissions deposited in the stratosphere remain there a long time. Because of the combination of these atmospheric characteristics, the altitude distribution of ozone, and the strength of the interaction of ozone with ultraviolet, the preliminary assessments show that lower altitudes result in much lower estimated levels for ozone depletion for a given amount of assumed emissions. However, a more thorough assessment that includes three-dimensional atmospheric models is required before any definitive conclusions can be reached.

Economic/Market Issues

Question 7: What assumptions are made to substantiate the economic viability of a high speed aircraft, e.g.,

*How many round trips per day are required?
*What Mach levels are assumed?
*Are overland flights assumed or dismissed?

*Are fare premiums required?
*What are the maintenance and turn around time assumptions?
*Are existing airports used?
*What type of fuel is used?

Answer 7: The number of round trips depends on aircraft scheduling and routing. On some of the primary long-haul routes, two round trips a day can be scheduled and still meet airport curfew requirements.

The High Speed Civil Transport Studies conducted under NASA contracts with Boeing and McDonnell Douglas over the past two years examined a broad range of Mach numbers. Of the Mach numbers considered, Mach 2.4 to 3.2 were the most promising cruise speeds for economic viability.

These studies examined operations with and without overland supersonic flight. Overland supersonic flight would improve the potential market for operations between some city pairs, but is not required for many over ocean routes in order to achieve an economically viable aircraft.

The requirement for fare premiums is dependent on the assumed technology level and airline seating mix. The goal is to achieve sufficient technology advances to avoid any requirement for fare premiums.

Aircraft turnaround times of one to two hours were assumed, with maintenance conducted overnight and at routine intervals, as currently used for subsonic transports.

Projected operations assumed the use of existing large airports.

Although other fuels were considered for higher Mach number vehicles, the most promising aircraft would use kerosene type jet fuel.

It should be noted that the High Speed Civil Transport Studies, on which these answers are based, were broad and preliminary in nature and involved many assumptions which were investigated in sensitivity analyses.

Question 8: What is the estimated dollar value of the high speed commercial aircraft market? What does this mean in terms of aircraft sales?

Answer 8: The estimated dollar value of the market, depending on the assumed period of production, would be within a range of $100 to 400 billion for a corresponding number of aircraft sales of 500 to 1500.

Question 9: Will the high speed commercial aircraft market be large enough to accommodate more than one profitable manufacturer during the first decade of production?

Answer 9: The ability of the projected market to support more than one manufacturer during the first decade is unlikely. The projected market of about 500 aircraft during the first decade of production is considered insufficient.

Question 10: How do recent concerns over aging and the need to replace a large number of the existing subsonic fleet aircraft influence this debate?

Answer 10: At this point, the recent concerns about aging aircraft have been assumed to have no influence on the projected market for high-speed transports. The current high-speed civil transport market projections are based entirely on the total estimated travel demand (without any assumed increases in demand because of the availability of higher speed travel), economics (estimated market capture based on fare and speed sensitivities), and comparisons with comparable advanced technology subsonic transports. Aging aircraft concerns can be expected to increase the operating costs of older transports because of increased maintenance costs and, as a result, may increase the transport replacement market and hence the total market, due to the earlier retirement of older aircraft. These effects are very uncertain at this point and, as such, have not been factored into the high-speed civil transport study market projections.

Technical Issues

The CRS report indicates that the technology currently exists to build a high speed commercial aircraft. However, without further research and technology, the report notes that such an aircraft would not very likely meet current and expected environmental regulations or compete economically with subsonic aircraft.

Question 11: What are the critical technologies required to address these concerns raised by the CRS report? Do we know enough about engines, fuels, airframes, avionics, materials, manufacturing methods, maintenance, operations and logistic requirements to build a reliable high speed aircraft?

Answer 11: The critical technologies required to meet the environmental requirements include low emission engine combustors, low noise engines and nozzles, sonic boom alleviation methods and other technologies that strongly affect the aircraft thrust requirements -- and hence directly impact the aircraft's environmental characteristics. The technology advances required for economic viability are those that most strongly affect the aircraft and engine efficiency and cost. These include propulsion system advances; long-life, high-temperature, cost-effective materials and structures; cruise aerodynamic efficiency and high-lift system advances; and advanced flight control systems.

The Concorde has already demonstrated that it is possible to build a reliable high-speed transport aircraft. But the Concorde's limited passenger capacity, range, and high operating costs restrict its operations to a relatively small market.

Question 12: To what extent are these issues being addressed by the aerospace industry?

Answer 12: The aerospace industry is working directly with NASA, on a cost sharing basis, in conducting the ongoing high-speed civil transport studies. In addition, the industry is currently examining alternative aircraft and engine design options and investing in technology development efforts in advanced materials, structures, and manufacturing methods.

Question 13: How much would it cost, and how long would it take, to reduce the technical uncertainties to a level low enough that industry might reasonably decide whether to invest in a high speed commercial aircraft project?

Answer 13: Results of a NASA/Industry planning effort estimated that it would take a total national effort of about $1.7 billion and 5 to 10 years to conduct the necessary research and technology development and validation efforts. These efforts were outlined in the Civil Aeronautics Technology Development and Validation Plan, prepared by NASA working with the U.S. industry, in response to a congressional request last year. This plan and associated R&D cost estimates were developed with the industry and reviewed by NASA's Aeronautics Advisory Committee.

Question 14: Are existing NASA personnel, facilities (especially wind tunnels), and computer installations sufficient to accommodate projected needs for both NASP (National Aero-Space Plane) and high speed commercial aircraft programs?

Answer 14: In general, the existing NASA personnel, facilities and computers are adequate to conduct both programs. This assumes operating with some strain on the available manpower and some small additions, such as the proposed Supersonic Low Disturbance Tunnel. Because these are high priority programs, we will make the manpower available. Our requested manpower augmentations will strengthen our ability to carry out these programs as well as improve our core capability. In addition, plans and programs are in place to revitalize our unique national wind tunnels.

Question 15: To what extent does the current National Aero-Space Plane research and technology program benefit the development of a high speed civil aircraft? And to what extent would NASP technology be applicable to a high speed civil aircraft?

Answer 15: The applicability of the NASP technology to the development of a high-speed civil transport depends on the Mach number that is eventually chosen. At the lower Mach numbers, where the current studies indicate the most promise for economic viability of a high-speed civil transport, the direct applicability of NASP technology is somewhat limited. The NASP technologies of most interest are the advanced analytical prediction and design codes and some of the high-temperature materials and structures technology.

Question 16: What should be the critical elements of a technology development program -- key milestones and decision points?

Answer 16: The technology program is in three phases: The first phase is the environmental research covered in the proposed High-Speed Research program. If clear progress is made in resolving the environmental concerns in the first phase, the second phase would be initially aimed at technology addressing economic viability. If clear progress is made in each of these phases, a third phase could be considered to provide technology validation.

Question 17: What should be the final objective of NASA R&D efforts on high speed commercial aircraft?

-- basic research
-- generic technology development (materials, airfoils, engine cycles, etc.)
-- manufacturing methods and processes
-- technology demonstration/validation (engines, cooling systems, avionics, etc.)
-- prototype production involving key technology elements
-- purchase of a series of precursor aircraft to meet government needs
-- other

Answer 17: The primary objective of the NASA R&T efforts on high-speed civil transports is basic research and generic technology development. However, in order to verify certain critical technologies, very limited manufacturing methods or process technology efforts may be required to define the appropriate materials and structures technology, and limited, highly selective technology validation efforts may be necessary. The NASA R&T plans do not include prototype production or the purchase of precursor aircraft.

Governmental Policy Issues

International Issues

Question 18: Should the official posture of the United States be to "go it alone" in high speed commercial aircraft R&D or to enter into international programs at the outset?

Answer 18: It would be inappropriate for NASA to comment on what the official posture of the U.S. should be without extensive interagency consultation.

Question 19: Should the government take positive action to prohibit U.S. firms that participate in NASA-related high speed commercial aircraft R&D consortia from sharing the technology so developed with foreign firms?

Answer 19: Major technology advances are required in order to provide the basis for the industry to develop a successful high-speed civil transport that can meet the necessary environmental and economic requirements. Developing these technology advances in certain critical areas are the key to securing a strong competitive position for the U.S. industry. Because of the high leverage of these technology advances, restrictions are available under the Arms Export Control Act (AECA) and the Export Administration Act (EAA) to protect certain technologies. NASA itself would require some relief from the provisions of the Freedom of Information Act in order to not be compelled to disclose property and sensitive information.

Advanced technology will place the U.S. industry in a strong negotiating position for developing any future international cooperative aircraft development efforts.

Civilian Aviation System

Question 20: What changes in the operation of the civilian aviation system would be required to facilitate the entry of large numbers of high speed commercial aircraft in the early 21st century? If changes are needed, will they be acceptable to the subsonic part of the industry?

Answer 20: The planned National Airspace System upgrades are considered adequate to facilitate the entry of high-speed transport aircraft into the aviation system in the early 21st century. In addition, the noise profiles of the high speed commercial aircraft will have to be developed and evaluated in terms of their impact at airports served.

Question 21: Will the operation of a fleet of high speed commercial aircraft interfere significantly with the operations of essential military operations, and how should such interference be managed?

Answer 21: It is expected that the operation of a future fleet of high-speed transport aircraft can be accommodated using the same procedures that are currently in place to handle military/civil operations.

Question 22: Will existing noise regulations, especially those regarding ground level noise impacts near airports, need to be modified to accommodate these operations?

Answer 22: Although FAR 36 - Stage 3 represents a very challenging requirement, these existing noise regulations have been assumed as the goal for future high-speed civil transports. Current airport noise estimates for the future high-speed civil transport concepts under consideration indicate that it may be possible to reduce the noise footprint considerably. It appears feasible to satisfy the noise requirements at the FAR 36 takeoff and landing measurement locations, but that it will be difficult to meet the sideline noise requirement.

Question 23: Will additional investments in airport and air traffic control infrastructures be needed, and how should they be paid for?

Answer 23: It is not expected that future high-speed transports will require any additional investments in airport or air traffic control infrastructures.

Question 24: Would operational high speed commercial aircraft need special consideration in airport and airspace operations, such as preferential landing rights, and would this be acceptable?

Answer 24: It does not appear that future operational high-speed civil transports will require any special consideration in airport or airspace operations.

Government/Industry Cooperation

Question 25: Is the traditional model of NACA-NASA/industry cooperation in aircraft development adequate as the basis for developing a high speed commercial aircraft? Or would a SEMATECH-like model in which industry does most of the research with partial government funding and limited government guidance be more appropriate?

Answer 25: The proposed High-Speed Research program will not, and is not intended to develop a high speed commercial aircraft. For the proposed R&T effort, the traditional model of NACA-NASA/ industry cooperation is considered appropriate. The past record of accomplishment is excellent using this model. The proposed high-speed R&T program will make extensive use of the NASA facilities and personnel expertise. At this time, and in this phase of the program, a SEMATECH-like model does not appear appropriate.

Question 26: Does the new legislative environment for industry/government cooperation in research offer new opportunities, or new problems, for NASA/industry cooperation in this activity?

Answer 26: It is unclear at this time how the new legislative environment on industry/ government cooperation will affect NASA/industry cooperation in conducting the proposed high-speed research effort.

Question 27: Is it reasonable to expect financial or technical participation in the conduct of a R&D program by firms in various sectors?

Answer 27: The industry has already demonstrated a willingness to share the cost of the high-speed civil transport studies. It is reasonable to expect the industry to continue to participate in the R&T efforts by supplying wind tunnel models, ground test hardware, and in other ways.

Question 28: Would government recoupment of its portion of the R&D costs be required from any successful commercialization programs that result?

Answer 28: Effective procedures and policies are already in place for NASA recoupment of government R&D costs when these costs directly support the development of a product or product improvements. We do not expect that this will be the case, since NASA's programs are oriented toward basic research and generic technology, not product-oriented development.

Question 29: What sort of formal industry and/or environmental advisory committees should be established to guide NASA high speed commercial aircraft R&D efforts?

Answer 29: Several committees are already in place. A NASA Aeronautics Advisory Committee Ad Hoc Review Team on High-Speed Transport has been operating effectively over the last two years to guide the NASA research efforts. Also, the Aeronautics and Space Engineering Board of the National Research Council has routinely reviewed the ongoing NASA high-speed research efforts. In addition, an atmospheric working group, made up of some of the world's leading atmospheric scientists, has been established to guide the high-speed transport atmospheric research. NASA has the appropriate flexibility to modify its advisory committees as research and technology needs dictate.

Budget Outlook

Question 30: In light of the serious budget pressures facing the Nation, can a high speed commercial aircraft program be undertaken without doing damage to the proposed space program including the space station program?

Answer 30: The proposed High-Speed Research program funding is extremely small in comparison with the space program. Based on the interest of foreign governments in high-speed transport aircraft and the threat this poses to our industry, it is clear that this research is of a very high priority.

Question 31: What is a higher budget priority -- the National Aerospace Plane X-30 Program or the High Speed Civil Aircraft Program?

Answer 31: The NASP and High-Speed Research programs are very different and complimentary in nature. The NASP program is aimed at probing the technology frontier of transatmospheric flight with the development of the X-30 research aircraft. The High-Speed Research program is aimed at resolving the environmental issues for future high-speed civil transport aircraft. As you are aware, the Space Council is currently reviewing the NASP program.

Question 32: What is NASA's best estimate of the cost of high speed commercial aircraft? Does this assume federal acquisition of a military or other precursor product?

Answer 32: It has been estimated that the total cost for industry to develop a future high-speed civil transport, including a new propulsion system, could be as high as $10 billion. The projected price for an individual future high-speed civil transport is around $200 million, depending on the resulting aircraft size, range, and cruise speed.

The CHAIRMAN. Dr. Rosen, with respect to the percentage of NASA funds for research and technology that is recommended in the National Research Council report, did they recommend 8 percent for research as the portion of the NASA budget. And I think the Payne Commission was 6 percent and the House Science, Space, and Technology Committee recommended 10 percent.

Is it true that you now only provide some 2.5 percent of the NASA budget for space research and technology? Is that right now?

Dr. ROSEN. That is right, Senator. But let me add at this time that, while that is considerably below those other figures, we have a growth budget. The OAST space technology budget has grown considerably in the last three years, and in fact we are double what we were just two and a half years ago.

The CHAIRMAN. So even though the percentage is small, you really have been increasing the effort?

Dr. ROSEN. That is right, that is right.

The CHAIRMAN. What is the appropriate percentage, do you think?

Dr. ROSEN. Well, I think those committee recommendations, those reports, would probably put us in the right range. But to tell you the truth, Senator, we are so far from there at this point that we would have to get a lot closer to know exactly what the right number was.

The CHAIRMAN. Well, do you have any documentation over at NASA that shows the relationship between the funding for pre-development space research and technology and the development costs of the major initiatives?

Dr. ROSEN. Yes, sir. We have done some studies and taken a look at some of the work that we have done where there has been extensive pre-development work and where there has been very little. And there is a significant difference in the total cost of the system if you have done the pre-development work as opposed to if you are just really doing the research along with the program itself.

There are tremendous cost savings involved with having the technology in place before you begin the program.

The CHAIRMAN. Should we do some earmarking? In other words, if the United States is to have a technology base to really implement the future missions and reduce the risks of ongoing operations, should we earmark a set percentage of the final NASA budget for space research and technology?

Dr. ROSEN. Well, Senator, I think what you are really asking is a difficult question. I think what we need to do is we need to increase our budget in general, and that is something that the Administration, the Administrator, and OASD clearly support.

I think at this point in time to decide to earmark a particular number would probably not be appropriate. What we need to do is to grow the budget, and we have taken those kinds of steps in the past and it is the intention of the Administrator to keep growing the technology budget to allow us to do the kinds of things that technology enables.

The CHAIRMAN. I have some other questions. Let me ask, Dr. Ballhaus, how high a priority is the 1990 budget request for NASP?

Dr. BALLHAUS. Senator, I consider it a high priority.

The CHAIRMAN. Higher than the new high speed commercial aircraft initiative?

Dr. BALLHAUS. Senator, that is a difficult question, because they are really aimed at different problems. The National Aero-Space Plane is a bold venture that stretches our technology development capabilities and that, if it is successful, will lead to flexible access to orbit.

The High Speed Civil Transport work is fundamentally different. That effort is aimed at taking advantage of what we see as a rapidly increasing requirement for long-haul international travel and the high potential that, if the United States does not move out within the next ten years on this activity, some other country will.

Now, the subsonic transport infrastructure in this country really is the key ingredient in our overall aeronautics program in the United States, and the biggest threat to that capability, which is now the prime contributor to the U.S. balance of trade, is the threat that someone else will develop a product that will make a significant percentage of our existing product line obsolete.

So I think it is important to pursue both programs. They are really aimed at different areas.

The CHAIRMAN. Well, suppose they kept it frozen at the 1989 level of $69.4 million for NASP. What would be the programmatic implication?

Dr. BALLHAUS. Senator, it would clearly stretch out the program, and I think there is a danger in doing that in that this particular program has done a tremendous service to the country, I think.

It has revitalized the hypersonic infrastructure in the United States, and that infrastructure was virtually destroyed about 15 years ago. We basically got out of that business. And the National Aero-Space Plane program has rebuilt that.

There is tremendous enthusiasm in universities, in industry, and in the national laboratories for this program. The companies have invested over $640 million in this activity to date.

I think if the government reduces its commitment to the program, you will see a loss of enthusiasm across the whole country among the 5,000 people that are working to support this effort, and in particular I think you will see a reduction in the commitment on the part of industry to commit their own funds to the activity.

The CHAIRMAN. Well, the DOD revised budget by President Bush, is that going to cut that amount again?

Dr. BALLHAUS. That is not clear at this time, Senator. In fact, last year the DOD went through a similar exercise where the Aero-Space Plane effort was initially reduced, and then it was finally restored.

We expect that the DOD, which certainly has very difficult budget problems at this point, will do whatever they can to support the activity. But it is not clear yet whether they are going to be able to support it to the full funding level required.

The CHAIRMAN. Well, if you note any frustration it is because I have got money, but nobody else wants to spend it. I have got a value added tax to pay all of these bills. And they talk about cutting, and we have done that for eight years.

Twenty-six percent of the budget is in defense. The President is asking for an increase. We would be lucky to level fund it, and particularly in the light of the many contracts that Cap Weinberger let. We just learned very quickly that it costs more to cancel a contract than complete it.

Another 48 percent is in entitlements. That encompasses social security, which is guaranteed an increase, not a cut, and health costs, which go up on an average of 11 to 12 percent every year, which is guaranteed an increase. If we just hold it down to 4 or 5 percent, rather than the 11 or 12 percent, you would be lucky.

So there is no real cuts in that 48 percent. You cannot cut the 16 percent interest cost even though that is the name of the game since what we are trying to do is cut those interest costs on the deficit.

So that leaves 10 percent for the rest of the government. It is like tying cats by their tails and throwing them over the clothesline. Everybody out here is clawing each other trying to get some money to keep things going and their head above water, whether it is the women, infants, and children feeding program, space technology, the defense bill, foreign policy or whatever it is.

And we go through the act that we are against taxes, we are against taxes. It is the sorriest government I have ever seen. We ought to pay the bill and we need the revenues to do that. We also need to get this government going again and quit crying around here and acting like we are doing the job.

I know you two have done an outstanding job and I appreciate your appearance.

Senator Gore will have some questions for the record.[1] We can excuse you at this time. Dr. Ballhaus, will you please stay right there for the next panel, because now we want to bring up Dr. Rowberg, Richard Rowberg, Chief Scientist of the Policy Research Division of the Congressional Research Service; Dr. John Swihart, Aerospace Industries Association; Dr. David Doniger, Senior Staff Attorney for the Natural Resources Defense Council; Dr. Norris Krone of the American Institute of Aeronautics and Astronautics; and Mr. Ronald Wickens, the Vice President of Engineering and Quality Assurance for Federal Express.

The Committee several weeks ago set the stage for a portion of this particular hearing by releasing the Congressional Research Service report "Commercial High Speed Aircraft Opportunities and Issues." We are very pleased this morning to have the chief of that particular section, Dr. Richard Rowberg, and his report. To prepare for this panel, we have submitted this report to each of you for your comments and your statements.

I think what we really need to do, if you do not mind, is sort of limit each of you to about 5 minutes. Let's see if you can summarize your positions across the board here, so we can have that much in the record.

Your full statements will be included, and then we can go to the questions.

Dr. Rowberg.

---

[1] See p. 576.

STATEMENT OF DR. RICHARD E. ROWBERG, CHIEF SCIENTIST, POLICY RESEARCH DIVISION, CONGRESSIONAL RESEARCH SERVICE, LIBRARY OF CONGRESS, ACCOMPANIED BY DR. CHRISTOPHER T. HILL, SENIOR SPECIALIST IN SCIENCE AND TECHNOLOGY POLICY

Dr. ROWBERG. Thank you, Mr. Chairman.

With me is Chris Hill, who along with Kathleen Hancock, now with the General Accounting Office, were the authors of the report that you just mentioned. This testimony which, I shall summarize, presents the principal findings of that report.

We found that the development of a competitive and environmentally acceptable High Speed Civil Transport would be a difficult technical challenge. Our inquiry, however, found no evidence of any fundamental technical roadblocks to meeting that challenge, although development would be risky and potentially quite costly.

We also note that other countries are starting modest but significant High Speed Civil Transport research and development programs, most notably in West Germany, France, Japan, and the Soviet Union. The potential for significant international competition clearly exists.

For an HSCT to be successful, it would need to meet strict airport noise and sonic boom limitations, add no significant damage to the ozone layer, and be competitive with long-haul subsonic transports. Current technology, while an improvement over the Concorde, cannot meet these goals.

While difficult, industry analysts are optimistic that they can be met with a well-structured research program. The objective of the NASA proposal is validation of technologies which would meet these goals.

The program would focus on propulsion systems, aerodynamics, structures and materials, and control systems. If this program succeeds, development of this technology could lead to an HSCT fleet early in the next century that could substantially improve productivity of long-haul air transport, and a lead role in developing an advanced HSCT technology by the United States could help maintain this nation's lead in commercial aircraft well past the year 2000, even if an international consortium were necessary to produce a commercial aircraft.

Of the three environmental concerns, protection of the ozone layer appears to be the most limiting at this time. Significant engine emissions, such as nitrogen oxides, could further deplete the ozone layer. Therefore, the prime objective of an engine development plan will be to reduce emissions to the point where no additional damage is done.

While such technology appears possible to many experts, it is not clear yet how well it will work or how it will affect HSCT operating costs.

Current engine technology also cannot meet stringent stage three airport noise requirements. Studies done for NASA indicate that these or even tighter standards could be met with future technology, although doing so will be difficult.

It is also unlikely that the public would accept significant sonic boom levels in populated areas, although we do not know now with any certainty just what level would be acceptable. Some modification and reductions in sonic booms are possible with advanced designs. Prohibiting supersonic flights over land or, at a minimum, over populated regions may impose substantial economic penalties on an HSCT.

Although a large market is likely to exist for an HSCT that is environmentally acceptable and economically competitive, there are a number of uncertainties. The market studies done for NASA assume that an HSCT would need to charge a ticket price premium, but that it could still be competitive with subsonic aircraft because of higher productivity.

In conclusion, the primary issue for the Congress is whether to authorize a formal program for NASA to develop the research and technology base for a new generation of High Speed Civil Transport. The decision would require balancing of uncertain future benefits that would accrue to the nation if an HSCT can be built and operated successfully against the costs of the program in a time of budget constraint and the fact that success cannot be guaranteed.

The Congress may wish to take action on several items in its oversight responsibilities should this program be approved. These include: obtaining a clear statement of the technical and economic assumptions and the goals of the programs and any changes in them; monitoring the interaction between the HSCT program and other relevant activities, such as research on the ozone layer, changes in the price of fuel, analyses of projected market conditions, and advances made in the National Aerospace Plane program; and initiating discussion of possible follow-on steps, such as possible government financial assistance and the possibility of international ventures for commercializing the new technology.

Thank you for the opportunity to testify, and we will be glad to respond to any questions.

[The statement follows:]

Testimony of Dr. Richard E. Rowberg
Chief, Science Policy Research Division
and
Dr. Christopher T. Hill
Senior Specialist in Science and Technology Policy
Congressional Research Service
Before the Subcommittee on Science, Technology and Space
Senate Committee on Commerce, Science and Transportation

April 4, 1989

Commercial High Speed Aircraft

My name is Richard Rowberg and I am Chief of the Science Policy Research Division of the Congressional Research Service. With me today is Dr. Christopher T. Hill, Senior Specialist in Science and Technology Policy of CRS. The two of us, along with Kathleen Hancock now of the General Accounting Office, are the authors of the recent Senate Commerce Committee Committee Print, Commercial High Speed Aircraft: Issues and Opportunities. This report was prepared at the request of the Committee to analyze a proposal by the National Aeronautics and Space Administration for a research and technology program to develop and validate technology leading to a commercial high speed transport. The analysis performed by CRS was based in part on a workshop held in May 1988 to address major technical, environmental, and economic issues associated with the proposed NASA program and possible aircraft development. The Congressional Office of Technology Assessment also provided analysis on issues concerning the air transport system. Our testimony presents the principal findings of the CRS report.

MAJOR FINDINGS

Development of high speed civil transport (HSCT) technology by the National Aeronautics and Space Administration (NASA) and the United States aerospace industry has been called for by many as part of a major program in aeronautics research and development to help the United States keep its world lead in the commercial aircraft market well into the next century. For a high speed civil transport to enter the market, however, it will need to meet strict limits on airport noise and sonic boom levels, add no significant damage to the atmospheric ozone layer, and be competitive with a new generation of efficient long haul subsonic aircraft. Technology exists today to build an HSCT, but it would not meet these goals. While there is now no way to determine in advance whether these goals can be met, NASA and industry officials are optimistic that an economically competitive, environmentally acceptable HSCT can be built. Further, analyses done for NASA show that if an HSCT can be developed which meets these economic and environmental goals, a substantial market will exist in the first decades of the next century. Development of this technology could lead to an HSCT fleet early in the next century that could improve substantially long haul, air transport productivity.

Developing an acceptable HSCT would present a difficult and potentially very costly technical challenge to NASA and the U.S. aerospace industry over the next 10 to 20 years. To meet these challenges, NASA has developed a proposed cooperative government-industry, multiyear technology development and validation plan at the request of Congress. The objective of the NASA plan is to advance key technologies in hopes that the operating cost of a commercial HSCT would be well below that which could be achieved using today's technology. The NASA plan encompasses neither construction of a prototype nor demonstration of major component systems, but is predicated on industry proceeding from the validation phase to develop a commercial HSCT. Because success is not assured, however, a Federal research and technology program to attain these goals would be a risky venture.

If the United States is to maintain preeminence in commercial aeronautics into the next century, the Nation probably would have to undertake this technology development and validation plan alone, or at least as the dominant partner. It is possible for the United States to do this, and, while NASA has not yet given a projected cost of the research and technology (R&T) program, current estimates are that it would require about 1.5 to 2 billion dollars (including both government and industry contributions) and 10 to 12 years to complete technology validation.

Beyond this R&T program, industry now believes that a prototype aircraft must be built to demonstrate the new technology before it would make a commitment for commercial production. Current estimates are that a prototype would cost between 5 and 10 billion dollars, but these costs are highly uncertain. As with the R&T program, no decision has been made yet about the construction of a prototype aircraft. Further, much of the industry now feels that commercial production of a high speed civil transport fleet probably would have to be carried out by an international consortium because of the aircraft's high cost and because other nations may demand some participation as a condition to operate within their territories. Nevertheless, many believe that in developing the prototype, Federal assistance would be necessary. Also, some feel international cooperation in HSCT technology development should be pursued.

TECHNOLOGY CONSIDERATIONS

The technology now exists--primarily as design, materials and engine knowledge and systems--to build a high speed civil transport (HSCT) that would have a greater range, capacity and speed than the Concorde. Such an HSCT would use technology developed by the U.S. SST program of the 1960s and the NASA supersonic cruise research program of the 1970s. Without further research and technology development, however, an aircraft using existing technology would very likely not be able to meet current and expected environmental regulations concerning airport noise and ozone layer protection, nor operate with a sonic boom level that would allow operation over populated areas. In addition, such an aircraft would not be able to compete economically with subsonic aircraft over those routes which would be served by an HSCT.

To meet these environmental and cost goals, therefore, at a minimum, a major research and technology program that focuses on propulsion systems, aerodynamics, structures and materials, and control systems probably would be needed. For propulsion systems, the target would be an improved variable cycle engine (VCE) using advanced materials that can provide considerably greater fuel efficiency over the entire range of flight speeds, and reduced emissions and noise levels compared with current VCE technology. In aerodynamics, the plan's objectives are designs and technologies leading to greater efficiencies by substantially reducing drag at both subsonic and supersonic speeds. Advanced materials development--primarily polymer and metal matrix composites--will be important to allow for significant weight reduction while maintaining structural integrity and operation in high temperature environments. An important aspect of materials development will be the need for manufacturing technologies designed to hold down aircraft construction costs. System and control technology development is needed to operate the aircraft at optimum efficiency and to maintain safety.

The current NASA proposal calls for a research and technology program addressing a potential HSCT in the Mach 2 to 5 (two to five times the speed of sound) range. Current subsonic transports cruise at about Mach 0.85 and the Concorde at Mach 1.8. The technical challenges for an HSCT flying above Mach 4 are considerably greater than for one flying at Mach 3.5 or lower. Above Mach 4 standard hydrocarbon fuels cannot be used. Instead, fuels cooled to very low temperatures (liquid hydrogen or liquid methane) will be needed in order to absorb much of the heat generated by air friction with the aircraft moving at those speeds. Similarly, materials requirements will be much more stringent. It is possible, however, that a Mach 4 to 5 aircraft would ease some environmental constraints imposed on aircraft flying between Mach 2 and 3, particularly if the former flies at considerably higher altitudes than the latter.

The National Aerospace Plane program (NASP), currently being conducted by NASA and the Department of Defense, is carrying out research on technologies for a transatmospheric vehicle with a design goal of flight up to Mach 25. The program's goal is an aircraft capable of flying directly from the ground into Earth orbit. While the NASP program eventually may evolve to a hypersonic (Mach 5 to 14 range) civil transport, the program has not yet started to explore this regime. As the NASP program is currently being conducted, much of the technology being developed in it probably will not be applicable to the development of any high speed civil transport program in the Mach 2 to 4 range. For an HSCT in the Mach 5 range, however, there is likely to be greater contribution from the NASP program, particularly with materials and engine technologies.

ENVIRONMENTAL CONSIDERATIONS

Of the three environmental concerns, protection of the ozone layer appears to be the most limiting at this time. Analyses indicate that current damage to the ozone layer resulting from deposition of chlorofluorocarbons (CFC) and other gases will take a century or more to be repaired. Any significant emissions that could further deplete the ozone layer, such as nitrogen oxides from aircraft engines, will likely not be acceptable because of the potentially harmful environmental and health effects of further ozone depletion. Therefore, a prime objective of a propulsion system development plan for an HSCT will be to reduce emissions so as to do no more harm to the ozone layer. While such technology appears possible to many experts, it is not yet clear how it would affect HSCT operating costs. Also, some analysts are concerned that if fuel additives are used to reduce NO_x production, these additives may generate harmful emissions.

An important parallel program would be expansion of studies on the effects of HSCT emissions on the ozone layer and to make sure these studies are closely coordinated with other research efforts on the earth's atmosphere being carried out by NASA and other Federal agencies. To address the scientific and related policy questions about protection of the ozone layer, which is of global concern, it may be very desirable for the United States to maintain a leadership role in these efforts.

Such leadership could help enhance acceptance worldwide of an HSCT developed primarily in the United States.

The current technology for HSCT engines--the variable cycle engine--is unable to meet stage three airport noise requirements (currently the most stringent). Current analysis indicates that these or even tighter standards could be met with future technology although doing so will be difficult. The noise pattern at ground level for subsonic aircraft meeting stage three standards would differ from that of a supersonic aircraft meeting the same standard. There is concern, therefore, that while these noise targets may be met when the noise is integrated over the monitored region, the peak noise from an HSCT might exceed limitations. If this is the case, the Federal Aviation Administration may wish to consider alternative noise measuring procedures, although local concerns must be accommodated.

It is unlikely that sonic booms significantly greater than 1 lb./sq. ft. overpressure from an HSCT fleet would be acceptable in populated areas. This is the restriction under which the Concorde must fly. While in principle it is possible to design a Mach 2-3 HSCT which produces a sonic boom below 1 lb./sq. ft. at ground level, such designs now appear to be impractical with current or projected technology. Because it would fly at a much higher altitude, it may be possible to build a Mach 5 or above HSCT which produces an acceptable ground level sonic boom. The alternative of prohibiting supersonic flight over land or, at a minimum, populated regions, may impose substantial economic penalties because of the aerodynamic design compromises required to get the best possible combined subsonic and supersonic cruise efficiencies. The configuration to achieve maximum efficiency at supersonic speeds is not compatible with that needed for maximum efficiency at subsonic speeds.

MARKET CONSIDERATIONS

High speed commercial transport aircraft are intended to achieve two goals: reducing the costs of air transportation services and travel time for both passengers and freight over long (above 5000 km) routes. For a successful HSCT lower costs would result from the fact that a greater number of seat-miles would be deliverable each day compared with subsonic aircraft of the same capacity. This could occur even if the capital costs per seat and fuel consumption per seat-mile were higher for an HSCT than competing subsonic aircraft, assuming that maintenance and turn around times can be held acceptably low.

Current forecasts by NASA sponsored analyses show a very large market for an HSCT _if_ it is environmentally and economically acceptable to the public. These assessments, however, assume that fare premiums are likely to be necessary and that these premiums would range from 15 to 75 percent over subsonic fares depending on seating class. At these premiums, these same assessments find that an HSCT may be economically competitive with subsonic aircraft for routes longer than 4000 km because of the time savings realized. The possibility that fare premiums will be needed, however, may be damaging to the prospects for an HSCT. The image of being an aircraft that is available only to those sufficiently well off financially to pay high fares could severely hamper the public's acceptance of a Federal role in HSCT research and development. A target of _no_ fare premium appears highly desirable.

If an HSCT must fly at subsonic speeds over land to comply with restrictions on sonic boom, the economics of the aircraft could be compromised. Whether this would prevent an HSCT from being economically competitive with subsonic aircraft is not yet clear. Some important routes that lie mostly over land--e.g., New York to Tokyo--could be precluded for an HSCT flying with sonic boom restrictions. Since the HSCT will be an international carrier, access to foreign territories and airports is essential. This is likely to be an important determinant in considering international involvement in any HSCT production consortium.

AIR TRANSPORT SYSTEM CONSIDERATIONS

While upgrading the air transport system is of major concern in the United States--regardless of HSCT developments--improvements on a global scale are likely to be much less significant for the development and acceptability of an HSCT for international travel than the other considerations described above. One concern is the availability of fuel. Since an HSCT in the Mach 3 range probably will not use Jet A fuel--JP-7 fuel instead--new fuel storage and handling facilities would be needed at all airports served by an HSCT fleet. Such facilities would be considerably more costly if liquid hydrogen or methane were used (Mach 4 and above) than JP-7. Also, to minimize time loss due to unscheduled maintenance and repair, airlines would have to establish specialized repair facilities at several HSCT terminals.

The economics of an HSCT fleet would require that ground turn-around time be kept to a minimum. It would be important to the airlines operating HSCT aircraft that the international air traffic control system function more efficiently than it now does. Greater air traffic system efficiency is a major concern for the entire airline industry, however, and such steps may be taken even in the absence of an HSCT fleet. Indeed, the HSCT offers the hope of leveling departure and arrival peaks and allowing for improved destination weather prediction accuracy because of its much shorter flight times. Also, flying at a greatly expanded range of altitudes could reduce international air traffic control pressures compared to a situation where only subsonic aircraft operated.

POLICY AND PROGRAM CONSIDERATIONS

The primary issue for the Congress is whether to authorize a formal program for NASA to develop the research and technology base for a new generation of HSCT. The decision would require a balancing of the uncertain future benefits that would accrue to the nation if an HSCT can be built and operated successfully against the costs of the program in a time of budget constraint. The Congress may wish to take action on several items in their oversight responsibility should the HSCT program be approved. These include: obtaining a clear understanding of the assumptions and goals of the program, and any changes in them; carefully monitoring the interaction between the HSCT research and technology program and other, relevant activities such as research on the ozone layer, changes in the energy situation and analyses of projected market conditions; and initiating exploratory work on possible follow-on steps such as financial assistance mechanisms and international ventures.

Given the nature of the proposed NASA program--no major demonstrations of technologies or prototypes are planned--a precise definition of technology validation appears to be lacking. In particular, it would be important for NASA to clarify how it intends to demonstrate that it has achieved the operating cost reduction goals which now seem to constitute the principal measure of validation.

The Federal budget pressures that now exist raise the possibility of severe competition with the space program for funds. This competition could be intensified if the Nation decides to expand space efforts to any extent. In addition, an HSCT program might also find itself in competition for personnel resources with other aeronautics programs such as the National Aerospace Plane and advanced subsonic aircraft.

The current proposal calls for NASA to lead a joint industry-government project as in past NASA (and NACA) projects. While industry feels that this organizational structure is the best way to carry out the HSCT program, the size and complexity of this proposal are such that it may be useful for the Congress to explore alternative cooperative research arrangements.

Beyond the research and technology program lie decisions about how to proceed to a commercial HSCT fleet if the goals of technology validation are met. It now appears that realization of a commercial HSCT fleet would require some type of government assistance. Most industry representatives believe that the development costs will be so high that no manufacturer would be able to recover them for any reasonable projection of fleet size. Some Federal assistance methods that have been suggested are a guaranteed government buy, government financing of the prototype and various financial incentives such as tax credits or guaranteed loans. At this time, no one method appears to offer clear advantages, although it is difficult to make an accurate assessment since so little is known about the eventual development costs of the aircraft.

An international consortium of aerospace firms is also a possibility for development of an HSCT fleet. Indeed, most industry representatives believe an international effort would be necessary because of the ultimate cost. Even with such a consortium, however, some government assistance appears to be necessary to proceed with the production stage.

CONCLUSIONS

The development of an competitive and environmentally acceptable HSCT fleet would be a difficult technical challenge. Our inquiry found no evidence of any fundamental technical roadblock to meeting that challenge, although development would be risky and potentially quite costly. Further, there are indications that other countries are starting modest but significant HSCT research and development programs. Most notable are programs in West Germany, France, Japan and the Soviet Union. Clearly the potential for significant international competition exists. This factor, too, is an important consideration for the Congress in deciding on what role, if any, the Federal government should take in assisting the development of a commercial high speed transport. Thank you for the opportunity to testify and we will be glad to respond to your questions.

The **Chairman**. Very good.

Mr. Swihart.

STATEMENT OF JOHN M. SWIHART, PRESIDENT, NATIONAL CENTER FOR ADVANCED TECHNOLOGIES, AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA

Mr. **Swihart**. Yes, Mr. Chairman, members of the Subcommittee:

My name is John M. Swihart. I am the President of the National Center for Advanced Technologies, a non-profit foundation formed by the Aerospace Industries Association of America. In addition, I served as the chief engineer at Boeing for the United States' Supersonic Transport production development effort in the 1960's and 1970's.

It is with pleasure that I address some of the issues of a second generation High Speed Civil Transport on behalf of NCAT and the AIA. The AIA is the trade association representing the nation's manufacturers of commercial, military, business aircraft, helicopters, aircraft engines, missiles, spacecraft, and related components and equipment.

The mission of the National Center for Advanced Technologies is to serve as a focal point for coordinating United States research and development efforts for eight key technologies identified by the AIA as crucial to the United States' competitiveness in aerospace.

The technologies currently being addressed by the program are: advanced composite materials, very large scale integrated circuits, software development, propulsion systems, advanced sensors, optical information processing, artificial intelligence, and ultrareliable electronic systems.

Among other things, these technologies will be key aspects of the effort to develop a commercially viable High Speed Civil Transport aircraft.

Considering only routes over 2,500 miles long, there will be at least 400,000 passengers per day who want to fly by the year 2005. If any HSCT can be made economical enough for an airline to make a profit, the market for the airplane will be well over 1,000 units.

This will result in a total business potential of at least $250 billion and possibly $300 billion. The impact of such a business potential on the United States' balance of trade is enormous.

The technology required to make an airplane that can operate at one-tenth the seat-mile cost of Concorde, while carrying perhaps three times as many passengers as Concorde, at twice the range and being an environmental good neighbor, is not available to us today.

The engine for an HSCT must make no more noise around the airport than our current best subsonic airplanes. It must also produce exhaust gas emissions that have no significant effect on the world's ozone layer or, perhaps more precisely, must not cause an increase in ultraviolet radiation reaching the earth.

The airplane itself, if flying over land at supersonic speeds even below its design cruise speed, must not cause a startling sonic boom.

These environmental concerns are paramount and must be attacked and understood before any significant moneys are spent on the design of an HSCT.

We need to work very hard over the next eight to ten years on structural materials, specifically composite materials for lightweight structure. Work must be done on advanced propulsion systems, ultrareliable electronics, advanced optics, and support materials. We need our best efforts with our supercomputers to optimize the aerodynamics and perhaps even achieve supersonic laminar flow for very high cruise efficiency.

To make an economical airplane, we will also need to program new, more efficient manufacturing methods. We must blend our new computer technology with our business systems, engineering and manufacturing so that we remain the world leader in commercial aircraft.

Work on a high speed transport will not just produce an airplane for rich businessmen. This work will spur the development of technologies of utmost importance to the United States.

In my view, the United States' industrial preeminence flows from a uniquely American gift of the ability to combine technological innovation with entrepreneurial spirit. We expect to see significant spinoff benefits that could be applied to areas such as conventional aircraft, electronics, and other industries.

The effort to develop the High Speed Commercial Transport will be as important for spinoffs, some of which can now only be guessed at, as it will for the creation of the airplane itself. The historical evidence from earlier aerospace ventures demonstrates that we can expect the effects to be felt in other industries and everyday aspects of life, and we must not miss this opportunity.

In summary: One, there is a very significant market for a viable HSCT;

Two, the maximum potential for an economically viable, environmentally sound HSCT is for a 300-passenger, 5,500 to 6,000 nautical mile range airplane, flying at speeds between roughly 1,600 and 2,200 miles per hour, Mach number 2.4 to 3.2.

Absolute environmental and economic viability is uncertain at this time, but the projected technology looks promising.

Aggressive technology development and validation is required to achieve the necessary performance and economics.

NASA and the industry together must develop the key technologies.

Industry should develop the airplane on its own, based on the mature technologies.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Swihart.

Dr. Ballhaus.

Dr. BALLHAUS. Senator, international air travel has become an integral part of today's global marketplace, and nowhere is this more true than among the rapidly emerging economic powers of the Pacific Rim. Long-haul trans-Pacific travel is currently the fastest growing market and is expected to nearly triple by the turn of the century.

Because of this projected rapid growth and the extremely long flight time for subsonic aircraft, there will be an increasing need for future high-speed aircraft to provide more effective service.

While subsonic transports will continue to be an important economic segment, these high speed aircraft will be the next plateau of competition in the international aviation arena. The competition for the high speed market, which studies indicate may be able to support only one product, will be intense.

The United States should be a key player in this critical segment of air transportation if we expect to retain a favorable trade balance and world leadership in aeronautics. NASA-sponsored studies have indicated that, with sufficient technology development, these future high speed aircraft could be economically competitive with long-haul subsonic aircraft.

Currently, however, critical environmental concerns about atmospheric impact, airport noise, and sonic boom present powerful private sector disincentives.

The fiscal year 1990 NASA High Speed Research Program will address these barrier environmental issues and develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental issues will place the United States in a position to make informed decisions on high speed aircraft technology development in the future.

The program builds on NASA's extensive efforts in upper atmosphere research and experience in airport noise reduction technology and sonic boom reduction. The atmospheric research addressed in this program involves two elements: long term atmospheric chemistry assessment and low emission combustion research.

The long term atmospheric chemistry assessment will use sophisticated atmospheric particle transport models and complex atmospheric chemistry models to analyze the potential long term effects of aircraft emissions on the stratosphere. In parallel with this effort, the low emission combustion research will develop and test alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs which produce very low amounts of NO_x emissions.

The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression, aimed at providing the same acoustic levels achieved by today's quietest subsonic aircraft. This research will expand on the results of previous acoustic research, to include anechoic chamber tests of advanced technology jet noise suppression designs.

Airport noise calculations will examine projected levels for alternative aircraft and engine systems.

The third element of the program, sonic boom reduction, includes aircraft configuration research aimed at reducing the sonic boom levels, combined with human response evaluations to define the criteria for acceptability. Aircraft configuration research will focus on design analysis and wind tunnel testing of low sonic boom configurations, as well as analysis and experimental research on supersonic laminar flow control.

Selected flight research efforts will be conducted to verify the analyses and wind tunnel test results. The F-16XL aircraft which we recently obtained from the Air Force will be used as a flying test bed to investigate the feasibility of applying laminar flow control techniques developed for subsonic transports to supersonic flight with delta wing aircraft.

Just to emphasize one point, Mr. Chairman, it is not our intent to start an SST program. Really, what NASA is trying to do is take the longest lead technology item and address it, and that is the potential environmental impact, to see if we can overcome what we consider to be a fairly significant barrier issue.

The CHAIRMAN. Very good.

Dr. Krone.

STATEMENT OF DR. NORRIS KRONE, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Dr. KRONE. Mr. Chairman and members of the Subcommittee:

On behalf of the American Institute of Aeronautics and Astronautics, we appreciate the opportunity to present our views of the NASA aeronautics budget and particularly the High Speed Civil Transport initiative.

It is our perspective that the High Speed Civil Transport is a natural product of the technological advancement in aeronautics and associated systems sciences, just as the 600 mile an hour jet transport was a natural technology progression from the 300 mile an hour prop aircraft that it replaced in the 1960's.

The environmental issues—sonic boom, airport noise, and ozone depletion—are viewed as inputs to the design requirements of such an airplane and have the effect of making performance objectives—speed, range, and payload—more difficult to attain. But they are design constraints, just as, for example, temperature limitations on materials are design constraints.

NASA's effort to better define and understand these phenomena is a proper and necessary step. It essentially is defining those design constraints. We vigorously support those activities.

However, the environmental issues should not be viewed, in our opinion, as barriers. Hurdles would be a better way to describe them, hurdles that will definitely be overcome in the future.

A decision to proceed with a prototype will be based on technical and analytical judgments. But these judgments most certainly will have uncertainties. It is not necessarily true that our judgments will be the same as competitors. For example, the Japanese we understand are looking for partners right now to pursue such a project.

Now, turning to the NASA 1990 aeronautics budget, we believe that the key to overcoming the barriers and attaining the design solutions or those hurdles that have been mentioned here this morning is a strong technological aeronautical science program, primarily involving aerodynamics, structures and materials, and propulsion.

When we look at the NASA aeronautics budget, we see that those technologies—aeronautics for example is about the same percent of the NASA, aeronautics total budget, as it was in 1989, it is in 1990. As a matter of fact, structures and materials is a little bit less as a percentage of the total aeronautics budget. Propulsion is about the same.

The High Speed Supersonic Transport—or Civil Transport, is viewed as a near-term benefit, as opposed to the NAS program, National Aerospace program, which is viewed as the longer term, to have longer term benefits. They are not the same relative to the technological challenges.

One is looking at a totally different and very ultra-high speed flight regime and looking to develop a feasibility, to prove a feasibility, whereas the other one is looking at a much lower flight regime and looking to develop the economic value of aircraft designed in that flight regime.

In conclusion, we will strongly support the NASA 1990 budget and endorse a stronger High Speed Civil Transport activity involving those key technological disciplines I mentioned.

Failure to meet this challenge could possibly lead to a large economic forfeiture, as well as the loss of our leading position in the world's aviation industry. With a projected world market of over $550 billion during the next 10 years, we think that we must make the necessary investments to meet the challenge.

Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you, Dr. Krone.

Mr. Wickens.

STATEMENT OF RONALD WICKENS, VICE PRESIDENT OF ENGINEERING AND QUALITY ASSURANCE, FEDERAL EXPRESS

Mr. WICKENS. Thank you.

Before moving into the subject of commercial aircraft and in particular high speed commercial transport needs, I want to take a few minutes to introduce you to my company, Federal Express, our philosophy, and our values. I want to share with you how our CEO's, Fred Smith's, commitment to excellence results in what is certainly one of the most amazing business success stories in this century.

This story highlights our commercial high speed transport needs. It demands a high speed commercial transport aircraft for the world logistics system.

Federal began operating its express package business in April 1973 with eight packages on the first night. By this December, some 16 years later, there is a good chance we will move 1.7 million pieces per day.

Since 1975 we have sustained a growth rate of approximately 35 percent, doubling our business every 18 months for the past 14 years. Consider the following: At our current revenue-producing rate, Federal generates more revenue every two days than we did in the entire year of 1975; 1976 is surpassed in five days; 1977 in 10 days; and as recently as 1981, 55 days.

The 1989 acquisition of Flying Tiger Line, once integrated, will leapfrog previous growth records. Our new international system needs a high speed vehicle. In mid-1977 we had 2,800 employees and 32 Falcon mini-freighters, a 6,000 pound payload airplane. Today Federal Express and Flying Tiger combined have 70,000 employees, a fleet of 19 747's, 24 DC-10's, 6 DC-8's, 86 727's, and 125 Cessna 208's. This equates to a total lift capacity of more than 12 million pounds.

Each of our new DC-10/30 freighters in our fleet has approximately the same lift capacity as the entire 1977 fleet of Dassault Falcons.

July 1975 marked the first time that Federal Express reported a profit. Since then, our emphasis on service has led to one of the most enviable and sustained profit growth records in the last 13 years.

Since our first public offering of stock on April 12, 1978, Federal Express has performed three to four times better than the Standard & Poor's 500. A 1978 investment of about $70,000 sold today would be worth more than $1 million.

Within Federal Express we are accustomed to rapid rates of change, and we perceive several major trends that will shape our need for aircraft as we approach the twenty-first century. These trends are the product of shifting societal and economic forces within the worldwide external environment.

The first of these trends is noise. Over the past few years there has been an escalating level of community objections to airport noise throughout the United States, particularly during nighttime hours. Those of you that are familiar with our system know that our primary operations occur at night.

Our short-term concern, of course, is that a portion of our fleet could become re-regulated by the developing new noise standards. One of the major priorities within our engineering section is the development of a stage three compliant 727 aircraft. In conjunction with Pratt-Whitney, we will be completing certification of the 727-100 and 200 later this year.

Longer term, noise compliance will be a major factor in our choice of fleet additions to the FEC fleet. Thus, the High Speed Commercial Transport must be a quiet aircraft with worldwide acceptability. Curfews or noise restrictions must not limit its hours of operation.

The second trend and most important in the macro sense is the now well documented emergence of the true world economy. This emergence is particularly dramatic throughout the Pacific Rim countries of Japan, South Korea, Taiwan, and even China.

According to data obtained from the U.S. House of Representatives Committee on Science and Technology, the Pacific Rim is the fastest growing economic region on earth.

As early as the spring of 1981, Federal Express began to investigate the feasibility of Mach 2 aircraft. During that year we performed lengthy operational, technical, and economic analysis directed at moving high priority packages between Europe and the United States with the Concorde. This aircraft provided the opportunity for one-day service westbound from most of Europe to the United States Eastbound, it would have provided a two-day service and to Europe from selected U.S. cities a one-day service.

Although the idea was rejected at the time, it is characteristic of the Federal Express leading edge philosophy.

Unfortunately, the aerospace manufacturers think of their primary market as being the passenger aircraft. Freight aircraft are an afterthought. FEC today is converting passenger aircraft into freighters at the rate of two per month. Sixty aircraft purchased by FEC are in the queue awaiting the conversion.

One final word about Federal Express and the growing need to be competitive in the worldwide marketplace. Only 7 years ago the average price for Federal Express service was $24. Today that average has fallen to around $15. But even more important is the fact that our customers are getting more value for their money.

At the same time that our prices were falling nearly 30 percent, we enhanced our product. We went from a noon to a 10:30 service. We have increased the size, automation, and speed of our sort facilities. Our geographic coverage has expanded to include 99 percent of the population of the United States.

In 1989 with the acquisition of Flying Tiger, we will leapfrog ourselves into the international marketplace.

I present the Federal Express experience as a prototype of what American industry must do if it is to sustain a position of leadership in world affairs. As wave after wave of aggressive foreign competitors storm our beaches, it has never been more important to get our act together.

Nowhere is this more true than in the aerospace manufacturing industries. As recently as 15 years ago, the capital cost of a typical airline seat was in the area of $40,000. Today this seat will cost about $185,000, or nearly five times as much.

This represents an escalation far greater than the 350 percent inflation that we have experienced over the same time frame. It is true that the manufacturers are building in more value. The aircraft of today have two crew members, category 3B landing system, and stage three quietness, are safer and more reliable.

But this is not enough. Technological innovation is not just an American prerogative. The competitors are also technically innovative and have proven it by blitzing one industry sector after another.

Research and development is necessary, but we must learn to produce more efficiently and cheaply. In 1969 I worked for a major carrier that purchased Concorde aircraft options at $10 million per airplane. These option purchases were refundable if not exercised, but at the same time the manufacturers, British Aerospace and Aerospatiale, were allowed to escalate their prices depending on the cost of manufacturing.

Around 1974 my company at that time, along with other major U.S. and world buyers of these options, relinquished their options when the aircraft price quotes were at $44 million and escalating. Today the only buyers and operators of these aircraft are the British and French government-supported carriers.

The number one objective of the High Speed Commercial Transport aircraft for the aviation industry should be one of superior product and one that is manufactured within budget. It must be economically viable. The aerospace industry must gain control of their out-of-control seat and ton-mile costs to the airline industry or the United States by the year 2000 will no longer be a competitor.

In the past 7 years, Federal Express has lowered prices and significantly improved the value-added service that we provide to our customers. The same mentality must somehow be accepted by the aerospace industry in an attack on the aircraft cost structure. The future of America's leadership depends on such a strategy.

The CHAIRMAN. Thank you, Mr. Wickens.

Mr. Doniger.

STATEMENT OF DAVID DONIGER, SENIOR STAFF ATTORNEY, DIRECTOR, OZONE PROTECTION PROGRAM, NATURAL RESOURCES DEFENSE COUNCIL

Mr. DONIGER. Thank you, Mr. Chairman.

I am speaking today on behalf of the Natural Resources Defense Council, with 100,000 members dedicated to protecting public health and the environment. And I come to you as the Director of NRDC's Ozone Protection Project.

We have been working for a number of years to safeguard the ozone layer from chlorofluorocarbons and other ozone-depleting chemicals, and because of the concern over the ozone layer I was asked to participate in the CRS workshop.

Mr. Chairman, in making its decision whether to fund this plane or this research program, I think the Congress has to act in at least two capacities. The first and most important is as a trustee for the present and future generations of the ozone layer, our vital global shield against dangerous solar ultraviolet radiation. The question that must be asked is whether there is any reasonable chance that the HSCT project will yield a product that will not exacerbate the damage already done to the ozone layer.

The second capacity in which Congress must act is as a prudent investor of taxpayers' money. Is there any reasonable chance, given the environmental and economic obstacles that this project must overcome, that it can develop a financially successful plane, one that will repay the government's investment?

On the basis of my experience at the CRS workshop and the information presented in its report, I have concluded that this project cannot survive examination from either perspective. Due to the constraints imposed by the ozone layer, as well as sonic boom and airport noise and other considerations, the probability of the plane's environmental acceptability is extremely low. The probability of economic viability, already very low because of the projected cost of the plane, is reduced even further by the unlikelihood of resolving its environmental problems.

Thus, in my opinion, acting both as a trustee of the ozone layer and as a prudent investor of taxpayer money, Congress must turn this project down.

The ozone layer, as we have all learned, is already dangerously weakened by CFC's and related chemicals. Even if the emissions of those chemicals were halted today—and that is not in the cards—the ozone layer would still require more than a century to recover. It cannot tolerate any new insults.

The High Speed Commercial Transport plane will emit oxides of nitrogen (NO_x) into the ozone layer. At that altitude, NO_x compounds are ozone-depleting chemicals. While there is some prospect that NASA's research program could reduce NOx emissions, there is no reasonable basis to conclude that they can be eliminated.

With the ozone layer in its present damaged condition, there is no level of additional ozone-destroying NO_x emissions that Congress could dismiss as negligible.

The CRS report reviewed past analyses of the impact of supersonic transports on the ozone layer. All such analyses acknowledged that NO_x emissions would cause ozone depletion. Several estimates suggested small effects on the total column levels of ozone—the total amount from the top of the stratosphere down to the ground—but even these analyses acknowledged that ozone would be redistributed within the column, and that itself is a serious impact.

In other words, it is not acceptable to deplete the ozone layer and then "make it up" by increasing ozone levels in the troposphere. This is especially so given the recent understanding that tropospheric ozone is a greenhouse warming gas.

All those analyses, as the CRS report pointed out, were conducted before the arrival of the concrete evidence of accelerated ozone depletion that has developed during the past several years. We have learned of the Antarctic ozone hole, the similar contamination of the Arctic stratosphere, and the occurrence of global ozone losses at two to three times the rate previously predicted.

The models used in earlier reports about supersonic transports significantly underestimated true impacts on the ozone layer and, as the CRS report put it, they must be considered "suspect on empirical grounds." The true impacts of such planes would likely be much worse than previously predicted.

As a result, in its capacity as a trustee of the ozone layer there is no way Congress could approve a fleet of HSCT's that would add to the present problems of ozone depletion. And given the implausibility of successfully developing a NO_x-free engine, especially at a reasonable cost, Congress should decide against funding this project.

The same conclusions follow from the perspective of a prudent investor. What leaps off the pages of the CRS report is the utter inability of this project to pay its own way. NASA is projecting a research and technology development program over a 10- to 12-year period of $1.5 to $2 billion. Beyond that the government would have to put up, because private industry concerns will not, at least $5 to $10 billion more to build a prototype plane. And finally, the odds are that the government would have to provide a multi-billion dollar production subsidy, for the manufacturer.

Market studies show the likelihood of fare premiums, with the result that the plane would be used only by elite business travelers, or perhaps by elite business travelers' packages.

One market side effect of the plane might be to seriously undermine the viability of subsonic planes by siphoning off first class and business class fares to the high speed plane. The idea that the public would subsidize a plane to serve the elite and then see its own fares on 747's and DC–10's skyrocket is not a welcome one.

Market studies also show great sensitivity to whether the plane could fly supersonically over land. There is absolutely no reason to assume that constraints on over-land flight will lessen. Rather, if you have a larger fleet of high speed planes than the present Concorde fleet, the public concern about sonic boom and airport noise, let alone ozone depletion, would probably only increase.

Why would a prudent investor take this venture? Well, one argument is that Americans should build this plane, or at least undertake this research, before the Europeans, the Japanese, or the Soviets do. My first reaction is that there is only the flimsiest evidence that these countries have serious efforts under way. I wonder if we have an effort under way here to create and exploit a sort of "SST gap" paranoia.

My second reaction is that, even if there were serious indications that other countries were working on this plane, the United States should not be in such a hurry to lose money. The CRS report notes that, considering the full cost of the British and French governments' backing of the Concorde, that plane has never made any money. Perhaps having learned their lesson, the British and French intend to retire them at the turn of the century and seem to be in no rush to replace them.

Our country has a huge budget deficit. We should not be pouring money into a project as unpromising as this.

We have a huge knowledge deficit also. We do not know enough about the atmosphere, the extent of ozone depletion and greenhouse warming that we face from other causes, and the magnitude of the environmental consequences. The money proposed for this project can be far better spent supporting the scientific assessment work of NASA and other agencies, such as the EPA.

I urge you to reject the extraordinary and imprudent risks of the proposed program and to give the critical problems of our atmosphere and climate your attention instead.

Thank you.

The CHAIRMAN. Mr. Doniger, what effect does the space program have on the atmosphere and the ozone layer?

Mr. DONIGER. Honestly, sir, I do not know. I am not knowledgeable about the volume of emissions that you would get from the Shuttle or the other rockets. But I do know that if you had a large fleet of High Speed Commercial Transports, they would put NOx in the stratosphere, and we do not need it.

The CHAIRMAN. But there is no measurement that you have in mind?

Mr. DONIGER. In terms of some allowable amount of NO_x?

The CHAIRMAN. Yes. I am just trying to compare the two activities in my mind. I take it you support the space program?

Mr. DONIGER. Well, my organization has no position on the space program. We have neither opposition to the space program or support for it as an organization.

But it would be an interesting analysis to ask what the comparative impact would be of a fleet of such planes and their NO_x emissions compared to those that come from the exhaust of the rockets.

The CHAIRMAN. Dr. Ballhaus, do you know the NO_x emissions that would occur? Is there any kind of measurement that you could give the Committee on any kind of effect on the ozone layer of a High Speed Civil Transport?

Dr. BALLHAUS. No, Senator, I do not know off the top of my head, but we could try to supply something for the record.

The CHAIRMAN. Do any of the witnesses know? Dr. Rowberg, did you find anything from your study?

Dr. **Rowberg**. No. We tried to see what the contributions of the Concorde were, but because it is such a small fleet and a small number of flights it is almost impossible to get any good measurements.

So in terms of projecting, you cannot do it on that basis. Also, the engine would have to emit far less NO_x in any case.

Mr. **Doniger**. I would add that the rockets, of course, go through the stratosphere. They do not reside in it for long flight paths.

The **Chairman**. Mr. Bryan.

Senator **Bryan**. Thank you very much, Mr. Chairman.

I have a couple of questions, and if these have been previously answered since I arrived late, please indicate that so I do not invade upon anybody else's time.

But the question I had generally is, to what extent is there evidence that our commercial competitors, the Europeans, the Japanese, the Soviets in the military sense, are moving forward in this technology to develop a High Speed Commercial Transport?

Do we have any evidence? If there has been testimony, again, I will yield to whatever the record reflects.

Yes, Mr. Doniger?

Mr. **Doniger**. Well, all I am aware of, sir, is several pages describing the other countries' work in the CRS report. Only a page or two is all it takes to describe all these other countries' efforts, and they seem to have very small things going on.

And as the report points out and I point out in my testimony, the British and the French are prepared to retire the present generation of Concordes and not have any follow-on. They got tired of losing the money.

Senator **Bryan**. Dr. Ballhaus?

Dr. **Ballhaus**. Sir, I can take a shot at that question.

Senator **Bryan**. Please, if you would.

Dr. **Ballhaus**. I think there are several efforts in Europe, one in the Soviet Union that we are aware of, and efforts in Japan, and I could try to summarize those for you.

I think in Germany, for example, there is the Sanger concept that is being studied, which is a two-stage access to orbit type of vehicle. The first stage is an air-breather and it is envisioned that that first stage might also be a hypersonic cruiser. That is one effort.

The French are looking at a follow-on SST. They are involved in studies right now.

The Soviet Union has a hypersonic transport under study. I do not know the details of that.

The Japanese are also looking very seriously at engines for supersonic transports.

Senator **Bryan**. Dr. Ballhaus, could you or Mr. Swihart—I may be mispronouncing your name—could you tell us where you rank the United States' efforts in terms of these other efforts you described? Are we ahead, about on a par, behind, in terms of where the research and the state of the art leaves us at this time?

Dr. **Ballhaus**. Senator, I think in terms of supersonic and hypersonic technology the United States is ahead, and the reason we are ahead in hypersonic right now is because of the substantial investment we are making in the National Aeros-space Plane effort.

However, there are strong efforts in other countries, as we have said, and we need to certainly be aware of what is going on and face it.

Senator Bryan. Mr. Swihart.

Mr. Swihart. I have been privileged to sit in on the Japanese committee at MITI studying their supersonic effort, and I can tell you that they have plans under way to perform technological work in each of the areas that we are discussing.

They are not spending as much money as we are on it at this time, but they do have a concerted effort in Japan, led by MITI, supported by the airlines, supported by the industry and the national aeronautical laboratories. And they are working very diligently on projecting an engine, also.

Senator Bryan. Those members of the panel that are supportive of research—and I appreciate, Mr. Doniger, your position and respect it—are we approaching it with the correct model? That is, in terms of private sector-government participation?

Should we develop a Sematech type of approach? Should we develop some other type of approach? Share with us, if you would, what you think we ought to be doing in terms of our approach to the development of this technology?

Mr. Swihart. From the industry point of view, Senator, I think that the approach that we have at the present time is adequate. I think the joint effort that we are doing with NASA and industry, which is indicative of the kind of thing that we have done for many, many years with NASA and NACA before that when I was a member, I think that is probably the right approach at this time.

I think it is probably a little bit too early to see whether or not we need a Sematech approach, because the primary things are to attach the environmental issues that have been discussed before we start into hard work of that kind.

Senator Bryan. Yes, Dr. Rowberg?

Dr. Rowberg. I would like to add that in the report we discussed this issue a little bit, and we agree that at this point the NASA-industry effort looks the most promising. Continual oversight if the program is approved and if it grows would be important however to see whether other arrangements similar to Sematech would be more fruitful.

But at this point there is no evidence to indicate that a NASA-industry joint effort would not prove to be successful.

Senator Bryan. If one could rank—Dr. Krone, excuse me, I did not mean to cut you off.

Dr. Krone. I just wanted to make a comment from the point of view of the AIAA, and that is to make a comment that what we believe is that there will be an advanced High Speed Civil Transport. It is in our future. And the NASA programs to develop technologies are not only in support of that program or that future program, but do support the other types of aircraft that do compete in the world markets, on other words advanced subsonic airplanes, the commuter market, commuter aircraft, the rotor craft, et cetera.

So in our opinion, at least in my opinion, we would be essentially hiding our head in the sand to ignore that reality.

The environmental issues are real issues. We understand that they are real issues. I do not think we should be so pessimistic that we ignore the fact that technological advancement does overcome these types of hurdles. It can generate aircraft in the future that fly at lower—the hurdles can generate aircraft that fly at lower altitudes than we like to fly them, but it does not mean that we will not fly them at lower altitudes. Military aircraft have been flying supersonic for years and years now.

And granted there is evidence of environmental degradation, but we I do not think have clear evidence as to a percentage and the degree to which those military aircraft flying at supersonic speeds have done damage, nor do we understand totally in my opinion the balancing that is natural in the atmosphere.

Senator Bryan. Dr. Krone, I appreciate your response.

I am concerned. In 1969 we had as a country about 91 percent of the jet commercial transport market. It has declined to about 68 percent today. That is something that is of concern to this Senator.

Mr. Chairman, my time is up. Thank you very much.

The Chairman. Go right ahead. There are just a few of us here now. We do not need that time schedule.

Senator Danforth?

Senator Danforth. You can go on.

The Chairman. Do you want to?

Senator Bryan. I was just going to ask one other question if I could. And that is, you have discussed the High Speed Commercial Transport, and from a non-technical point of view is there an intermediate step? Right now commercial jets travel what, roughly 600 miles an hour? Is there a market for an aircraft that travels at 800 or 900 miles per hour?

Or are you saying to us, if we are going to make a major technological breakthrough, it has to be something in the range of 1,600 to 2,200 miles an hour, which as I understand from your testimony is what we are talking about with the High Speed Commercial Transport?

Mr. Swihart. Let me see if I can answer that, Senator. From a technological standpoint, one of the worst possible places that you can fly from the overall efficiency standpoint is about 800 or 900 miles an hour. Once we pass the region of below supersonic speeds to above supersonic speeds, it appears that the maximum productivity, the maximum efficiency that you can get out of the operation, is best, if you can say that, at about Mach number 2.2, 2.4, up to 3.2, as you go through there.

So if we move from subsonic, then we want to move into the region of Mach number 2.4.

Mr. Doniger. Senator Bryan, can I make a comment?

You made a comment a moment ago that you were concerned about the change in the U.S. percentage of the world market.

Senator Bryan. Yes, I am, I am very concerned about that.

Mr. Doniger. And I would agree with that. It is a very important industry from the point of view of our overall economic balance of trade and so forth.

The question that has to be asked is, if you want to increase the percentage of sales that the U.S. commands, where should the money go? And I think that a broader inquiry should be made about whether it should be in improving the subsonic planes, getting more efficient engines, engines that use less fuel, create less noise, less pollution.

Senator **Bryan**. Well, is that not what we are doing, Mr. Doniger? I mean, have we not in the last decade seen an improvement?

Mr. **Doniger**. Yes, we have.

Senator **Bryan**. In terms of noise, energy efficiency, and that sort of thing?

Mr. **Doniger**. Yes, we have seen improvements. But there are many improvements still to be made there. And the question is where should the priority of the Federal money go if there is going to be any Federal money supporting R&D into this industry.

You can probably purposely design a plane which is a guaranteed money-loser and then we would all agree that that was a bad one to put the money into. Here of course, there has not been an effort to do that on purpose, but we still have to ask ourselves, does this plane make economic sense. And I do not think that we have seen any proof that it does.

Senator **Bryan**. Mr. Doniger, I am not trying to be contentious. I do not think my line of questioning is mutually exclusive with improvements in what we are presently flying.

My concern is, if there is going to be a major technological breakthrough, I want it to have an American flag on it.

Thank you, Mr. Chairman.

The **Chairman**. Senator Danforth.

Senator **Danforth**. Today, we have a very distinguished panel, and I am going to address my questions to Dr. Ballhaus. If anyone else wants to jump in, fine.

I attended a conference several weeks ago and one of the presenters at the conference took the position that the NASP program is one of the most promising things that we do. He said that it should receive much more attention than it has received in the past, and that it is much more promising, according to this person, than the space station. He believe that we should be placing more of our resources into the NASP program.

Do you agree with that assessment, and are we allocating enough resources to NASP? And if we are, should we be shifting resources from say the space station into NASP?

Dr. **Ballhaus**. Senator, I think we are allocating the right amount of funding to the Aero-Space Plane program at this time, and I would not favor a reallocation of money from the space station to support Aero-Space Plane, because I think we are already adequately funding Aero-Space Plane.

Senator **Danforth**. Does anybody else wish to add anything, or is that the consensus?

Mr. **Swihart**. Well, Senator, I support Dr. Ballhaus' statement. I think I personally believe that the National Aero-Space Plane is in the very best United States interest. It is exactly what we should be doing with our government money, funding things out on the cutting edge.

Every technology in that airplane is as far out as we can reach. The results of that will flow back to other efforts as we go. I believe we are doing it adequately at this time.

Senator DANFORTH. Now, would you explain to me, a total nonscientist and a humble lawyer from the Midwest, why the NASP program is such a good program? What is important about it?

How is it important to somebody who does not know science at all, and how would you justify or explain the importance of this program to that person?

Dr. BALLHAUS. Senator, I think there are several reasons for it. Number one is hypersonics is going to be a very important flight regime in the future and, as I mentioned earlier, this program has done a tremendous amount to revitalize the hypersonic infrastructure in this country.

I think Mr. Swihart just stated that in another way. It is stretching us in a wide range of technology areas very aggressively. That is very important.

The second reason I think is that if this program is 100 percent successful, it is going to lead to what you might consider the ultimate launch vehicle. It will allow you to have flexible access to orbit with a machine that can take off and land horizontally like an airplane, turn around fairly rapidly, and carry reasonably sized payloads into space, including humans.

So I think there is tremendous potential. But it is a high risk effort, and it is the kind of thing that I think the government ought to sponsor.

Senator DANFORTH. Does it have any possible commercial or nonmilitary applications?

Dr. BALLHAUS. The Aero-Space Plane program is not intended to be an operational vehicle at this point. It really is a technology program. But if you look downstream at what will come out of these technologies in terms of operational vehicles in the future, there is a wide range of potential military and civil vehicles that could come out of this program.

It is not a prototype, though. It is truly a technology demonstration effort.

Senator DANFORTH. And your belief is that if the United States wants to be on the cutting edge, as you put it, of technology, this is one area where we have to commit resources?

Dr. BALLHAUS. Yes, Senator, I do.

Senator DANFORTH. Thank you, Mr. Chairman.

The CHAIRMAN. Mr. Swihart, what altitude does the Concorde fly at?

Mr. SWIHART. Concorde flies at roughly between 50,000 and 55,000 feet.

The CHAIRMAN. I asked that question because in the preliminary findings of that Advisory Committee on the High Speed Civil Transport, they said higher speed cruise altitudes produce a dramatic increase in the predicted ozone loss. Cruising at 59,000 feet has twice the impact of 53,000, and 65,000 has twice that of 59,000.

So I go back to Mr. Doniger's answer about going higher. At first I thought the whole thrust here was to go higher—and you are the engineer who developed the SST. But what we are really trying to do is get a low altitude High Speed Civil Transport. Is that not right? Rather than a higher altitude? Or am I wrong in that?

Mr. SWIHART. Well, I think that the very preliminary results that you are quoting certainly give us pause for concern. But I think we have got to develop not only one-dimensional, but two-dimensional and three-dimensional models of the atmosphere to totally understand that.

In fact, I do not believe that there has been any measurements made of the amount of ultraviolet radiation reaching the earth yet at this particular time, regardless of all the discussion about whether we have got holes or this kind of thing.

So I think it is much too early to decide those particular points until we get a very much better handle on what the atmosphere is in real-life effects, so to speak.

The CHAIRMAN. I am more impressed with Mr. Wickens' elite packages! The reason for that is I found in my experience that my State of South Carolina had an entire agricultural income of about $387 million. In the State of California—we had a 100-year start on California before they even founded California—in just one county, Fresno, they had an income of over $389 million.

And it was because of the high speed delivery of those agricultural products from California to the New York market. They were growing strawberries and zipping them in before I could even get them picked.

So it might sound snide to talk about elite packages, but the Pacific Rim is such a market. Its GNP will exceed that of the United States and Europe combined by the year 2000. So it is this area we are thinking of, I guess, when we talk about the market for this aircraft. It is a delivery system to Tokyo, is that not right? New York to Tokyo, is that what you are describing, Dr. Ballhaus——

Dr. BALLHAUS. Well, that is one route, but so is San Francisco to Hong Kong is another. There are many long haul international routes.

The CHAIRMAN. Right. But I mean, in essence from the eastern seaboard where the production is occurring as far as this country is concerned, into that Pacific Rim.

Dr. BALLHAUS. That is correct.

The CHAIRMAN. And economically, if you can take two trips a day to Singapore and back—I understand one trip a day would not pay for itself—the aircraft would pay for itself. And in addition you would have the spinoff of the technology findings and developments, is that correct?

My worry is that we will go ahead and do the technology research and then we will sit and palaver over it, like we did the superconductor, and the Japanese will pick it up and develop it. And like Senator Bryan, who wants to develop it for the United States, I do, too. And that would be one of the big concerns.

Senator Danforth, you had an earlier question about technology information. Earlier today, I asked Dr. Ballhaus about the transfer of technology, where we forbid it in one provision of the law, but then under the Freedom of Information Act you can come to NASA and get the technical information anyway.

So we do not ship the product because that would be technology transfer but we ship all the technological information, and they develop the product.

Does the creation of the NASA High Speed Civil Transport Atmospheric Advisory Committee—I understand Bob Watson, who is the chief scientist for the Montreal Protocol—Dr. Ballhaus, does that give the necessary environmental and aerospace communities assurances that the environmental issues will be fairly addressed, do you think?

Dr. **Ballhaus**. Senator, I believe it does, because we have people from a broad range of communities on this issue on that committee. I have known Dr. Watson for a number of years. In fact the center I represent, the Ames Research Center, has done extensive studies on the ozone layer. In fact, we managed the expeditions to the Arctic and the Antarctic with our high altitude aircraft, the ER-2 and the U-2's and the DC-8, over the last couple of years.

So we have a very strong interest in ozone depletion from a science standpoint. And I know Dr. Watson at NASA headquarters has been a prominent spokesman in that area.

The **Chairman**. Yes, sir.

Mr. **Doniger**. I would like to comment on that. I have the highest respect for Dr. Watson, too. It seems as though, if we are going to go down this road, a committee with him and some of these other members is going to be one potentially effective way of making sure the right questions get asked.

But what I sense is that Dr. Watson may have been drawn in to examine, well, how can the plane's impact on the ozone layer be minimized, knowing that there was virtually no chance going in of making the impact on the ozone layer zero.

So Dr. Watson and that committee will probably be able to monitor and help develop the information on what this plane would do to the ozone layer. But I do not think that a NASA scientist is the best situated to critique whether a plane designed by another part of NASA would be benign to the ozone layer. It is always important to study the consequences of what we do, but we should take some heed of the knowledge that we already have about the problems this plane is inevitably going to cause.

The **Chairman**. Well, we might get you appointed to the advisory committee.

And Mr. Wickens, on your elite packages to Tokyo, how often do you fly out there? Every day, twice a week, or what?

Mr. **Wickens**. Once a day, sir, on the FEC system. We will integrate Flying Tiger and FEC later this year, and we have more landing slots in Tokyo at that time, as well as Osaka. So we will expand——

The **Chairman**. Pull that microphone a little closer.

In other words, what's really arresting, holding you back at the moment is the landing slots, is that right?

Mr. **Wickens**. With the purchase of Tiger, we in essence bought landing slots at Tokyo and Osaka. So when we get the two systems integrated, we can move packages on the Tiger and so forth. We are not fully integrated yet.

The **Chairman**. Has Federal Express found it economically feasible to deliver packages by way of the Concorde or supersonically?

Mr. **Wickens**. We evaluated that, as I said in my testimony. We were very close to striking a deal with British Aerospace. And the one thing that we asked the countries of France and Great Britain is that they guarantee the certificate of the airplane for a ten-year period. And they would not guarantee that, so we backed out.

The **Chairman**. Do you have any more?

Senator **Bryan**. Mr. Chairman, just one last question.

Mr. Swihart, in response to the Chairman's question about at what altitude ought we to be contemplating flight, you seemed to give rather short shift to the concern that has at least been voiced in every publication that I have seen in the last year about the depletion of the ozone layer.

From a non-technical point of view, as Senator Danforth is candid to acknowledge, I mean, everything that we read, everything that we hear, everything that we see suggests that the thinning of the ozone layer has serious environmental consequences, the most prominent of which is the increase in the incidence of skin cancer.

Are we being oversold in this concern, or do I misunderstand your answer to the Chairman?

Mr. **Swihart**. You totally misunderstood what I meant, Senator. I am sorry to have left you with that opinion.

Senator **Bryan**. I will give you a chance to clarify the record.

Mr. **Swihart**. I am just as much concerned about the ozone as anyone else. And the preliminary findings from a one-dimensional analysis I believe are what the Senator, the Chairman, was quoting. All I can tell you is that when you take the real atmosphere as it is right now, in the one-dimensional analysis, including the chlorine that is present, small amounts of nitrogen oxide introduced into that atmosphere actually increased the ozone.

And so therefore, with that preliminary analysis taken into account, it is unclear at this particular moment whether or not an HSCT would have any detrimental effect, considering the fact that we are going to reduce the emissions from the engines a great deal, as to whether it would have any detrimental effect whatsoever.

And what I meant to indicate was that we must thoroughly understand that particular problem. We are not going to spend money as an industry on starting to design an airplane until we thoroughly understand the environmental effects—ozone, sonic boom, and noise. And we need two-dimensional and three-dimensional, maybe even four-dimensional, models of that atmosphere that we can really get our hands on before we can understand that thoroughly.

Senator **Bryan**. Thank you, Mr. Swihart.

Thank you, Mr. Chairman.

The **Chairman**. And to complete the thought, just ruminating about these packages, for example, if I am going to deliver 20 packages to Tokyo, do I deplete more ozone by loading them here and flying them to Anchorage and then refueling and then flying them to Tokyo, than I do flying them directly from Washington to Tokyo by the High Speed Civil Transport?

I do not know. I am trying to measure what depletion there is from the Concorde and what depletion there would be from this new plane, should it be designed and developed, as compared to what I am depleting right now.

And Dr. Rowberg, did you find this out or make any comparable measures in your report?

Dr. **Rowberg**. Not of the potential from a High Speed Civil Transport, because of the small fleets. But there probably is some depletion going on from subsonic fleets, and I think there is increased awareness of that, and you see increased attention being paid in the newer generation of engines in that respect.

These are technical problems and they are difficult. Our report does find that they will need to be solved. But at this point, nothing we have found indicates that they are fundamentally unsoluble.

The CHAIRMAN. Well, once again, the apologies of Senator Gore, our Chairman, and all of us understand and sympathize why he could not be here.

We appreciate very much this outstanding panel's appearance here today. The committee has additional questions that will be submitted for the record.

We will stand in recess until the call of the Chair.

[Whereupon, at 10:56 a.m., the Subcommittee was adjourned.]

NASA AUTHORIZATION

TUESDAY, APRIL 11, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met at 9:57 a.m. in room SR-253, Russell Senate Office Building, Hon. John D. Rockefeller IV, presiding.

Senator ROCKEFELLER. The meeting will come to order. The chairman, who is filling in for another chairman, apologizes for his late arrival. And Senator Pressler has an opening statement. And I also have a statement that Senator Hollings would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

Today, the Subcommittee on Science, Technology, and Space will review the fiscal year 1990 NASA Space Science and Applications budget request.

The fiscal year 1990 budget request presents an interesting situation for the Subcommittee. On the one hand, it proposes a major new start that consists of a mission to the comet Kopff/asteroid fly-by and a mission to the planet Saturn. But on the other hand, it proposes the termination of the Gravity Probe B Mission, no funding for the Advanced Communications Technology Satellite—two programs strongly endorsed by the Senate Commerce Committee—and no new start for the Earth Probe Program, a series of ozone and tropical rain forest measurement missions.

This dichotomy reflects the critical challenge for the Subcommittee and for NASA this year, trying to prioritize program funding in light of the constrained fiscal environment.

I know I speak for the whole Committee when I indicate my concern with this request and with the mix of space science and space applications funding. The Committee is committed to maintaining U.S. scientific leadership, but it also is committed to U.S. technological leadership in existing and emerging space markets including communications and materials processing. The Administration's zeroing out of the ACTS program for the fourth time does not manifest a commitment on the part of the U.S. to dominate space communications. As noted in the report of the Business Higher Education Forum, "Space—America's New Competitive Frontier":

"America's steel, auto, consumer electronics and clothing industries all have been victimized by overseas competition and the U.S. lead is threatened in several other areas of commerce. It is ironic that the nation that has made the greatest contribution of space technology to the world should now be in danger of losing that lead as well.

"The facts, however, are undeniably clear. According to the Congressional Office of Technology Assessment (OTA), during this decade "advanced foreign capabilities have or will become comparable to those of the United States in virtually every area of civilian space technology except manned flight." Competition is especially prevalent in four areas: space transportation, satellite communications, remote sensing, and materials processing."

This is one Member who thinks we've lost enough markets and who is committed to a robust space applications program to prevent any further erosion of the U.S. market share.

I look forward to Dr. Fisk's testimony today, especially his outline of the robust space science payload flight program that will occur over the next two years including the flight of the first U.S. planetary mission since Voyager in 1978! There will be much to cheer for in the space science community during the next two years if all goes according to schedule.

I also look forward to Dr. Fisk's comments on NASA's future space science and applications mission profile including the Earth Observing System which is a critical element of an international global change program and an initiative strongly endorsed by this Committee. Interest in this particular mission is so strong that the Full Committee conducted a separate hearing on the Mission to Planet Earth on March 8.

Finally, I would like to thank our distinguished witnesses from the Space Science Board and the Space Science Working Group for appearing today. Their comments on the fiscal year 1990 NASA space science and applications budget request and the health and well-being of the space science community will be seriously assessed by the Committee as it formulates the fiscal year 1990 NASA Authorization Bill. I should indicate that the reports and inputs of both of these groups have influenced the scope and direction of the Nation's civil space program, and the Committee is grateful for Dr. Solomon's and Dr. Lanzerotti's testimony today.

We've waited a long time to get back in space, and we've waited a long time to see many of the payloads on the 1989-90 manifest launched. The next two years should be to space science what 1968 is to the manned space program—a time to remember and a time to aspire to new and more exciting challenges.

I look forward to today's hearing and to a very thorough discussion of the Nation's space science and applications program for the decade of the 1990's and beyond.

OPENING STATEMENT BY SENATOR PRESSLER

Senator **Pressler**. Thank you very much, Mr. Chairman.

I must go to greet the new President of El Salvador shortly, and I have read much of the witnesses' statements and I look forward to reviewing their answers to questions.

I would say that the Office of Space Science and Applications is perhaps the least politically protected office at NASA, and I have taken a special interest in it. I think that the whole space program has taken on a new perspective as we have learned about the warming of the Earth and our awareness of environmental problems has increased.

It is much easier to support the total NASA effort, aside from the Space Station and the Earth Observing System because now we know, and it has come into public consciousness, that we have to study the relationship between the warming of the Earth, the oceans, the atmosphere, and even how to predict earthquakes.

I have been working with Chairman Gore on one small part of this issue; maybe it is not small, but it involves the archives and the processing of the data that will be received from the hardware in outer space. I have a parochial interest in that we have the EROS Data Center near Sioux Falls, South Dakota, that receives the Landsat data and archives of them.

But I envision that center playing a role in archiving and in the information chain of future missions, because it is going to be a very big job archiving this information and making it presentable to scientists, universities, and decisionmakers in the next 10 to 20 years.

So I think the hearing today is extremely important, because we stand at the very beginning of a new era, in which we realize the importance of the environmental changes that are occurring, whether they be the forests in Brazil, the warming of the Earth or the changes in the ocean. And this is going to affect all our lives. And this office will be very important in this regard.

Although the Office of Space Science and Applications perhaps has been in the past the least politically protected part of NASA from a budget point of view, it may well become the most prominent because of the information it will provide.

The data that will be gathered in the next 10 years might well be similar to the library at Alexandria, as it was to the ancient Egyptians. Although it was burned by the Romans, it played a very significant part in storing the knowledge of that day.

And I would say that we are on the verge of collecting information that, if we can use it, will solve many of mankind's problems in the environment. That is the context for this hearing.

Senator **Rockefeller**. I thank you, Senator Pressler. And I hope I have not caused you to be later for whatever it is that you are going to be doing than you otherwise would have been.

Senator Bryan, do you have an opening statement?

Senator **Bryan**. No statement, Mr. Chairman.

OPENING STATEMENT BY SENATOR ROCKEFELLER

Senator **Rockefeller**. Then let me make one, just to set a context for the hearing. And again I apologize to Dr. Fisk and the other two witnesses for being late.

Today the Subcommittee on Science, Technology, and Space will conduct its fourth hearing to review the NASA fiscal 1990 budget. In particular, the committee will assess the budget request for the Office of Space Science and Applications.

As was true at our earlier hearings, the subcommittee will focus on the fiscal year 1990 budget and out year budget assumptions and their relationship to the approved and proposed space science and applications program. In particular, the subcommittee today will examine:

One, the new start requests for the missions to the comet CRAF and to the planet Saturn—the CRAF-Cassini mission; two, the proposed termination of the Gravity Probe B and Advanced Communications Technology Satellite programs; three, the status of the ongoing programs and activities; four, the overall health and well-being of the nation's space science infrastructure, including our university systems; and five, the status of future new starts for the Earth probes and Earth Observing Systems programs, EOS.

While the subcommittee is encouraged and impressed by the efforts of the Office of Space Science and Applications to institute a strategic planning process and a comprehensive strategic plan, the subcommittee is also concerned about this plan in that it is based upon potentially overly optimistic budget forecasts.

Hopefully, by the end of the week we will all have a better idea of what our budget is going to look like, because obviously there are rumors that there will be a budget summit and that the consequences will surface. That may or may not be true, of course.

Beside discussing the budget, we also hope today to get a glimpse of the space science activities planned for 1989 and 1990. Although it has been delayed almost three years because of the Challenger tragedy, the Year of Space Science has indeed finally arrived.

I know I speak for all of us as members of the subcommittee when I say we look forward to the April–May launch of the Magellan mission to Venus, the first planetary mission since Voyager in 1978, and also the launch of other major space science missions such as the Hubble space telescope, the Galileo mission to Jupiter, and the Ulysses mission to the polar plane of the sun.

Yes, 1989 and 1990 will be an exciting time for space science and for the nation's space program. But what about the future?

Over the course of the last few years, the subcommittee has spent a lot of time talking about leadership in space and the need to attract America's youth to science, to mathematics, and engineering. The Nation's space science program has a lot to do with these critical elements of nature's space program—of the Nation's space program, and with the public's perception of that program.

Recently there seems to have been a realignment in the space program from looking up to looking down, looking down at the planet Earth. For those of you who participated in the committee's Mission to Planet Earth hearing, that tendency was fairly clear.

There also has been a tendency simply to talk about the utilitarian aspects of the space program, such as materials processing and life sciences program that are seeking cures for life-threatening diseases and developing new wonder drugs.

The subcommittee therefore would like to talk about some of those problems today and to get a better appreciation of some of the benefits that we accrue from our science space and applications program.

Again apologizing for being late, I would like to say that I am glad that our witnesses are here today to discuss these issue. Dr. Fisk, I look forward to hearing from you today.

STATEMENT OF DR. LENNARD A. FISK, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY SAM KELLER, DEPUTY ASSOCIATE ADMINISTRATOR; AND CATHERINE SCHMOLL, ASSISTANT ASSOCIATE ADMINISTRATOR

Dr. **Fisk**. Thank you very much, Mr. Chairman.

I have with me Sam Keller, who is my Deputy, and Catherine Schmoll, my Assistant Associate Administrator. And back in the back are Joe Alexander and Bob Rhome, who are Assistant Associate Administrators with me.

If I may, I have a statement that I would like to submit for the record, and if I could just highlight a few of the points in it for you, if that would be all right.

Senator **Rockefeller**. Please do.

Dr. **Fisk**. The first point—I would like to make essentially four points, if I may. The first, as you noted, we are about to embark in the end of this month with the Magellan launch on what will be one of the most exciting eras in space science in the history of the space program. I like to think of this not just as the Year of Space Science, but of the several years of space science that are about to unfold before us.

There are 35 science and applications missions which are scheduled for launch over the next five years, and that is to say they are budgeted, they are under development, and they have a manifest slot on either a shuttle or an expendable launch vehicle.

And this is essentially the highest launch rate for science and applications missions in the history of the space program. You have to go back into the mid-1960's when the launch rate was a comparable number, and then it was about 35 or 36 as well in a 5-year period.

But of course, we were launching back then relatively simple missions, Explorer class missions, and now we are launching Magellans and Galileos and Hubbles and Gamma Ray Observatories and Upper Atmospheric Research Satellites and TOPEX's and so on. And so we are essentially going to be awash in new scientific data, new scientific discoveries, and I think it is a safe statement to make that our leadership in space science will not be in question.

The second point, again as you noted, we have a strategic plan for the Office of Space Science and Applications, one that we developed last year. We are in the process, as we plan to each year, of updating it on an annual basis. The new plan will be out within another few weeks. But the essence of the plan is not changed in any way. We changed the English a bit in a couple of places.

But we have a plan that we are doing our best to follow. We built the 1989 budget around the plan. We built the 1990 budget that you have before us. And if we have our way here, we are going to build all subsequent budgets according to this plan.

It gives us an opportunity to balance the need for major, moderate, and small missions. It gets us ready for Space Station, and it protects the research base at universities and NASA centers.

And it also allows us a process, a decision process by which we can adjust to various funding levels, one that gives us some aggressive growth and some which constrain our growth.

And I have been very pleased by the reception that this plan has had in the science community and in the Congress itself. In 1989 in the authorization bill, the plan was acknowledged and endorsed in general terms, and of course there were multi-year authorization language included in that authorization bill.

The third point, if I may, is to highlight the planetary exploration program because, as you noticed, this has of course been one of the jewels of the space program. This is a program in which we have really demonstrated U.S. prowess in space.

We have gone to exciting places. We have brought back stimulating, interesting pictures from the outer planets, and so on, and landed on Mars.

But in recent years we have fallen on hard times. The last planetary launch was in 1978 and the last planetary event was the Voyager encounter with Uranus in 1986, and almost no one remembers because it was almost coincident with the Challenger accident.

But this year we are going back to the planets and we are going back with really a flurry of activity, in which our leadership will no longer be in question. We have got the Magellan launch; we are still scheduled for April 28th. There is a Voyager encounter with Neptune in August of this year. It is really an historical event, the last planet that Voyager will see, the last of the grand tour, having gone to Jupiter and Saturn and Uranus and now Neptune.

In October we will launch the Galileo mission to Jupiter. And perhaps I think most important as a statement of our commitment that never again will the U.S. leadership in planetary exploration be questioned, we do have a new start in the budget for CRAF-Cassini.

CRAF goes to a comet, sends a penetrator into the nucleus; and Cassini goes to Saturn and sends a probe in to Titan, a satellite of Saturn.

And if you would look at this program that has been laid out before you in planetary, with the Magellan launch in April, the Galileo launch in October, Mars Observer launch in 1992, and CRAF and Cassini, you find that if you look at when these missions actually do their exploration, you are going to have Magellan at Venus from 1990 to 1992, or perhaps we can even extend the mission into 1993. You are going to have Mars Observer at Mars between 1993 and 1996. You are going to have Galileo at Jupiter between 1996 and about 1998 or 1999. You are going to have CRAF getting to its comet in about 2000 and going to 2002. And you are going to have Cassini at Saturn between 2002 and 2006.

And essentially, what we are going to do with both the launches this year, the new start this year, and a launch of Mars Observer in 1992, we will have put a planetary program into effect which essentially has a U.S. planetary mission doing its prime exploration phase continuously between 1990 and 2006. And nobody is going to question our leadership in planetary exploration again.

The fourth point I would like to make is just to emphasize, as I am sure my fellow Associate Administrators have or will in their testimony, is our concerns over the institutional issues at NASA. We have many responsibilities to deliver a first class space program, in my case space science program.

And I think the principal limiting feature in my being able to do that is the NASA centers, their personnel and their facilities. And I worry the most about that aspect of the program, the extent to which we can manage effectively the government's resources, the taxpayers' money, in being able to deliver these programs on time, on schedule, and on budget.

And the institutional issue is perhaps my largest single concern in being able to manage effectively the programs.

I am very pleased with the budget that we have before you. It has some holes and some weaknesses in it. I am sure we will talk about those. But I think it is a budget which follows closely the strategic plan for space science and applications, and that it will deliver a first class, world class space science and applications program.

And I would be pleased to answer any questions.

[The statement follows:]

April 11, 1989
OSSA Testimony FY 1990

Statement of

Dr. Lennard A. Fisk

Associate Administrator for Space Science
and Applications

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology, and Space
Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman, Members of the Subcommittee:

We have had an active and rewarding year since I last met with the Subcommittee to discuss the OSSA budget, but the best is yet to come. We are embarking on one of the most exciting eras in the history of the United States civilian space program. During the next five years we have scheduled for launch some 35 science and applications missions--payloads funded, under development, and manifested on either the Shuttle or ELVs. These five years will essentially match the highest launch rate for science missions in NASA's history. We will witness the flights of Magellan, Hubble Space Telescope, Galileo, the Cosmic Background Explorer, the Gamma Ray Observatory, the Upper Atmospheric Research Satellite and many Spacelabs -- all of which will provide new science data, new science discoveries and new science challenges. Our world leadership in space science will not be questioned.

Last year we introduced a strategic plan for the Office of Space Science and Applications (OSSA) which outlined our goal of continuing this level of activity well into the next century. The plan balances the need for major, moderate, and small missions. It provides a roadmap for assuring our readiness as major users of the Space Station Freedom. It maintains the research base at U.S. universities and NASA centers which are the key institutional components of the OSSA program. One of the most critical attributes of the plan is that it provides a flexible process for near-term decisions on the allocation of resources and planning for future efforts. I am pleased to say, Mr. Chairman, that this plan has been widely endorsed by the science community as well as by various Committees in Congress as a reasonable blueprint for the future of space science and applications in the United States. In fact, the FY 1989 NASA Authorization Bill was the first public acknowledgement and endorsement of the plan, and for that support we thank you.

I am pleased to say that the FY 1990 budget request that we will discuss today continues to follow the five basic themes which we originally conceived in the strategic plan. First, we continue to provide for the completion of the ongoing program in a timely manner. This month, Magellan will be launched to survey the surface of Venus using radar that penetrates the Venusian clouds, with resolution an order of magnitude better than any previous U.S. or Soviet mission. Later this year, we will launch the Cosmic Background Explorer (COBE), a free-flying Delta-class Explorer, to measure the cosmic background radiation which may be a remnant of the primeval explosion, or the Big Bang. In August, Voyager will make its last stop within our solar system, passing Neptune which has never been explored nor even viewed by mankind at a close distance. Just as in the case of Voyager at Jupiter, Saturn, and Uranus, we as a nation and as a global community will marvel at the wonders that Voyager will unveil at Neptune. In October, the long-awaited Galileo mission will be launched on an odyssey to Jupiter, sending a probe into the Jovian atmosphere and conducting a two-year tour of Jupiter's satellites. And finally, in December, we will launch the Hubble Space Telescope, which will revolutionize our knowledge of astronomy of the universe.

Second, the strategic plan allows us to move boldly forward in a key area of space science to ensure that our world leadership is preserved in the future. Last year we demonstrated our continued leadership in astrophysics with the start of the Advanced X-ray Astrophysics Facility -- AXAF. Our FY 1990 budget request makes a bold statement that the United States will regain its dominance in the field of solar system exploration. To renew our dedication to this particularly important field of space science, we have requested a new start for the combined Comet Rendezvous Asteroid Flyby (CRAF)-Cassini mission. The expansion of the frontier into the solar system begins with robotic exploration and unmanned planetary exploration -- a field which we pioneered and dominated since the beginning of the space age. In recent years, however, our leadership in this field has been questionable, since the last U.S. planetary spacecraft was launched more than a decade ago. Only Voyager and the smaller Pioneer Venus Orbiter, launched in 1978, remain in operation as planetary probes today. Nevertheless, with the two planetary launches and the new start of CRAF-Cassini, this year truly demonstrates the reemergence of U.S. leadership in the field of planetary exploration.

I would like to take this opportunity to briefly describe the CRAF-Cassini mission. CRAF will fly to the outer solar system, orbit a comet and send a penetrator into its nucleus. Cassini will orbit Saturn and send a probe into the murky atmosphere of its satellite Titan. CRAF and Cassini together explore the fundamental question of the origin of life.

First, it is believed that the material that formed the solar system is preserved intact in comets and in the giant outer planets such as Saturn. Second, it is believed that the early Earth did not contain sufficient water or perhaps even sufficient carbon to form life. The hypothesis is that the necessary water and carbon were brought here by comets colliding with the Earth. Finally, the early Earth was a much different place than we know today. Since the chemistry that gave rise to life in the past is no longer available for us to study, only by studying material essentially unaltered by the Sun's heat and radiation can we find clues to the origin of life. We believe that a chemistry similar to that on the early Earth, cold and slow in its reactions, exists today on Titan, a satellite of Saturn. CRAF-Cassini will study the material from which the solar system formed, the material from which life on Earth may have formed, and the chemistry that gave rise to that life.

The funding request for CRAF-Cassini is $30 million in FY 1990. The runout cost for the development program is approximately $1.6 billion distributed over seven years. This runout fits within a budget for the Office of Space Science and Applications which is relatively constant in constant year dollars, in FY 1990 and beyond.

We are facing a decision on a perishable opportunity. In a few years the alignment of the planets that made the Voyager grand tour possible will change, and a trip of reasonable length to Saturn will no longer be viable. Jupiter will have moved too far away to enable a proper trajectory. To gain the necessary momentum to reach a comet, our current launch capability dictates that a spacecraft must swing by Venus. However, the launch opportunities where Venus and a comet are aligned within a reasonable distance from one another are absent in the late

1990s. If CRAF-Cassini is not started now, the planetary launch window will not open again until the turn of the century. With the approval of this FY 1990 new start, we will create a planetary exploration program for the United States that is active, exciting, and respected well into the next century.

Let me be more exact. With the approval of CRAF-Cassini this year, the U.S. will have a planetary mission in its prime exploration phase continuously from 1990 to the year 2006. Our European colleagues have recognized the value of this scientific effort as well. The Federal Republic of Germany will join us on the CRAF mission, providing the Propulsion Module Subsystem and a scientific instrument. The European Space Agency will provide the Titan Probe for Cassini.

It is also important to prepare ourselves for the major initiatives of the future. Our FY 1990 budget request supports Advanced Technology Development in Earth Science and Applications to prepare for the Earth Observing System (Eos) instruments to fly on the Space Station Freedom's polar orbiting platforms as well as to fly attached payloads on the manned base. These instrument complements are being studied now so they will be ready for launch in the mid-to-late 1990s.

Mr. Chairman, I believe that the linkage between the Earth Observing System and the growing national concern over the environment is a strong one. Given worldwide emphasis and interest in global change, greenhouse effect, ozone depletion, etc., it is evident that there is a clear need to: 1) initiate a balanced program to acquire the measurements we can make now, such as Arctic and Antarctic ozone measurements; 2) continue support for the analysis of these measurements in the research and analysis base; 3) develop new observing capabilities such as the EOS instrument complement; and 4) develop the technology for future Earth system science missions. It is vital that a scientific understanding of the Earth system be obtained on a global scale. These plans are consistent with the efforts outlined in the Committee on Earth Sciences "Our Changing Planet" which accompanied the President's FY 1990 Budget.

As we follow the OSSA Strategic Plan, the Nation should envision 1991 as the year that the United States secures its leadership role in the area of Earth system science. Similarly, the OSSA Strategic Plan provides a clear map for the study of future Space Science and Applications programs including the Space Infrared Telescope Facility (SIRTF), Solar Probe, Orbiting Solar Laboratory (OSL) and Lunar Orbiter (LO) in order to assure that the United States never relinquishes its stature in these fields of science.

The third theme, providing for new flight opportunities in the near term for small missions, continues through the Small Explorer (SmEX) program which we began last year. We have just completed evaluating the proposals in response to the Announcement of Opportunity released last year, and on April 4 announced final selection. This program is well received and supported by the science community. I believe, Mr. Chairman, that several years from now we will be able to point to this initiative as an instrumental step in attracting new, young scientists and engineers into space science research. In the future, comparable initiatives in the Earth science disciplines will provide new flight opportunities in the near term and will be a valuable complement to our ever increasing need to better understand the delicate balance of the environment of the planet on which we live.

The fourth theme in our budget proposal allows us to move aggressively, yet sensibly, to build research instruments for the Space Station Freedom and its platforms. It is extremely important that we continue to develop the principal areas of space science and applications from which we will derive the greatest benefits by effectively using the Space Station Freedom facilities. Last year marked a leadership initiative in the area of microgravity science. The FY 1990 budget sets the stage for maintaining our leadership position in several critical program areas while establishing a firm foundation to support future initiatives.

In addition to continued support for microgravity science, the FY 1990 budget marks a leadership initiative in the area of life sciences. Substantial planning and preliminary research must be initiated in FY 1990 for the Extended Duration Orbiter (EDO) Medical Program to ensure pilot proficiency and performance during entry and landing and to ensure crew performance for both normal and emergency egress. Likewise, in FY 1990 Phase A/B planning for the Extended Duration Crew Operation (EDCO) project is required for the development and verification of suitable countermeasures to enable the Space Station program's baseline plan for crew cycling. This activity is essential to assure crew productivity and Shuttle fleet efficiency. Although the EDO medical program and EDCO are separate and distinct research and technological programs, they are sequentially supportive and make significant contributions to the initial studies for long-term agency requirements for extended piloted exploration missions in the future.

Another key initiative in our FY 1990 Space Station activity is the Space Biology Initiative Definition. The core of the space biology initiative is the equipment and facilities that will support the basic science elements in the space life sciences program during the 1990's. This program will focus on understanding the mechanisms that have evolved to detect and respond to gravity in living systems, and how adaptation proceeds in the space environment. This research will use traditional research methodologies applied in the unique environment of space to study fundamental biological mechanisms in plants and animals. The facilities developed in this program will also provide significant benefits which accommodate the scientific goals of other cooperating agencies, such as the National Institutes of Health and the National Science Foundation, and will enable relevant research with broad ground-based applicability.

The Space Biology Initiative for STS/Spacelab and Space Station Freedom payloads and the Space Life Sciences Extended Duration Crew Operations program are clearly defined integrated program elements that are designed to avoid resource duplication. They will provide the first opportunity to perform extended periods of essential and integrated biological and biomedical research since the Skylab era of the early 1970's. We can only speculate as to the immeasurable long term benefits to humankind from this research in areas such as osteoporosis, seed germination, and crop productivity. Based on this type of research, we will better understand life processes and their evolution at Earth gravity. The proposed initiatives in the FY 1990 budget are a natural extension of the major scientific thrusts described in the National Academy of Sciences report, "A Strategy for Space Biology and Medical Science for the 1980's and 1990's" and the strategies promulgated by the NASA Life Sciences Strategic Planning Study Committee in the report "Exploring the Living Universe: A Strategy for Space Life Sciences."

The four elements of our Space Station Freedom initiative--the development of microgravity facilities, the development of life science facilities, the development of attached payloads, and the selection and study of Earth observing instrumentation for the Polar Orbiting Platform--constitute a comprehensive plan by the space science and applications program to make full and integrated use of the unique opportunities that the Freedom Station will provide.

The final theme of the strategic plan promotes key augmentations to the Research and Analysis base, which is the foundation of our program. Mr. Chairman, as I stated last year, this area is the vital underpinning to our program as the base of support for a vigorous and productive research community. I am pleased to state that the FY 1990 budget allows for a revitalization and rejuvenation of this vital national effort. In preparing the FY 1990 budget, NASA together with the Office of Management and Budget, examined the Research and Analysis and Mission Operations and Data Analysis budget for the next five years and developed an approach which provides for a healthy research base not only in 1990 but during the next five years. This budget provides for the long term health and vitality of our university community. Being a former member of this community, I cannot stress to you enough the importance of this endeavor. We are making significant inroads in encouraging our young people to enter the fields of science, engineering, mathematics, and computer science because there is a future there for them and it is necessary for the health and well being of the country.

In closing, Mr. Chairman, I would like to emphasize one other critical element of the Space Science and Applications Program, namely the NASA Institution--the people, the facilities, and the resources. We have been assigned the responsibility to provide the United States with a first class civilian space program. To do so, the country must recognize that this requires adequate funding to: 1) hire and retain scientists, engineers, and managers to lead our world class science and applications programs; 2) develop and build world-class R&D facilities; and 3) provide resources such as travel funds to adequately manage and/or remain current in a field of expertise. We must ensure adequate support be continued for these activities.

The FY 1990 budget request permits us to complete the ongoing program and to build to the future, with the confidence that we are providing this nation with a space science and applications program that is second to none. In doing so, along with the entire civilian space program, we are making an essential contribution to the national welfare.

Before I briefly describe the specifics of our FY 1990 Budget Request, I would like to mention just three highlights of the past year -- aircraft/spacecraft observations of the Yellowstone Fires, Microgravity Science on STS-26, and the Airborne Arctic Stratospheric Expedition. These serve as examples of the return we have realized on our investment in space science and applications.

HIGHLIGHTS

1. Aircraft and Spacecraft Observations of the Yellowstone Fires

During late summer 1988, Yellowstone National Park was the scene of the largest mobilization of fire fighting forces in the United States. The fires in the park and adjacent areas have dramatically altered the landscape and ecological structure and behavior of a national treasure and stimulated debate about management of fire prone ecosystems.

During the fire, research aircraft based at the Ames Research Center flew multiple missions over the affected areas. These remote sensing aircraft were equipped with thermal infrared sensors and cameras that could "see" through the thick layers of smoke blanketing the park and national forest area. These data were transmitted in real time to the ground based Greater Yellowstone Unified Command. The availability of images of new fires and the advancing fire front yielded information on the size, speed and intensity of the fires which helped fire control officials prioritize their available manpower and equipment. In addition to the images provided by aircraft, the progress of the fires over state-wide areas was followed by images provided by orbiting spacecraft (Landsat).

Present plans call for ground and flight studies to document the damage and recovery of the National Forest and Park ecosystems. These proposed studies, to be jointly undertaken by the National Park Service of the Department of Interior, the Forest Service of the Department of Agriculture, and NASA, will map the extent and severity of burning, examine the success of natural forest regeneration and determine ecosystem effects, e.g. fire-related loss of soil nutrients. These studies should prove invaluable in determining future fire management policies and increasing our understanding of the effect of fires on forest ecosystem behavior.

2. Microgravity Science on STS-26

The 1986 Challenger disaster significantly delayed NASA and the free world's space flight opportunities. However, during 1988, space exploration resumed along with microgravity science investigations.

Two investigations were flown on the STS-26 mission: the

Automatic Directional Solidification Furnaces (ADSF), designed to process four Magnetic Metal Alloy samples by directional solidification in the classic Bridgman mode; and the Protein Crystal Growth (PCG) apparatus, designed to produce larger crystals in order to understand the complex structure of specific protein molecules. The following experiments were also flown aboard STS-26:

1) Isoelectric Focusing in Space (IEF) - A type of electrophoresis experiment which separates proteins in an electrical field; it was specifically designed to distinguish between electro-osmosis and electro-hydrodynamic (EHD) effects by varying the surface to volume ratio of the focusing cells.

2) Phase Partitioning Experiment (PPE) - Was designed to better differentiate the roles of gravity and other forces in separating or partitioning biological substances.

3) Aggregation of Red Blood Cells (ARC) - Was configured to provide information on the formation rate, structure, and organization of red cell clumps, and to investigate the potential beneficial role of microgravity in clinical research and medical diagnostic testing.

Preliminary analysis of the data received from some of these experiments is as follows:

PCG - 60 different experiments in protein crystal growth using the vapor diffusion method were performed on STS-26. Included among these were 11 different proteins, selected because they all display typical crystal growth problems under unit gravity conditions. For example, five droplets of the enzyme reverse transcriptase were flown on this mission. The reverse transcriptase enzyme is specifically responsible for the multiplication -- and therefore spread -- of the AIDS virus. Without this enzyme, it appears that the AIDS virus will not reproduce in the human body. It is therefore critical to understand this enzyme and its structure; Earth-grown crystals have proven totally inadequate. It is expected that space-grown crystals will allow important advances in understanding the enzyme's action and will point the way to the development of drugs much more effective than today's best therapy. While we were unsuccessful in our attempt to grow reverse transcriptase on this flight, results indicated that better purification of the samples would be needed before crystal growth would be possible. We will continue our efforts on future flights. However, initial x-ray diffraction results indicate that the crystals obtained for four of the other proteins flown display a structural order better than crystals of the same materials obtained on Earth.

IEF - Additional evidence to support findings on STS-11 experiments was obtained, indicating that the major source of convective turbulence is due to an electro-hydrodynamic effect, not electro-osmosis. Fluid protein behavior in focusing, although not fully explained, indicated even more turbulent behavior than observed in terrestrial controls. The onset of this turbulence was not synchronized with acceleration surges of the Shuttle.

PPE - The experiment consisted of a transparent module with 18 chambers of two-phase systems, each differing in various physical parameters (e.g., viscosity, volume fraction, and interface potentials). The PPE was configured to study two methods of phase separation (natural coalescence and surface tension) to allow variations in interfacial tension, phase volume ratio, phase system compositions, and added particles. The experiment was repeated three times and analysis of the data is proceeding.

Preliminary science reports are expected to be published in early 1989.

3. Airborne Arctic Stratospheric Expedition, 1989

The Airborne Arctic Stratospheric Expedition was undertaken to examine the chemical and dynamical processes that control ozone in the Arctic winter stratosphere. The overall goal of this mission was to establish whether the processes that contribute to the Antarctic ozone depletion are operative in the Northern Hemisphere.

For six weeks at the start of 1989, NASA and NOAA jointly undertook an Airborne Arctic Stratospheric Expedition to study the nature of potential depletion of stratospheric ozone over the Arctic. Between January 1 and February 15, 1989, specially instrumented NASA ER-2 and DC-8 aircraft flew some 20 missions over the Arctic and to the North Pole, allowing substantial penetration of the Arctic vortex. Flights were timed to coincide with the most active period for the formation of extremely low-temperature polar stratospheric clouds in the area. Such clouds are involved in the complex processes that result in the destruction of stratospheric ozone measured over the Antarctic.

Additional national and international project and scientific support was provided by the National Science Foundation's National Center for Atmospheric Research, the Chemical Manufacturers' Association, Harvard University, the University of Denver, Pennsylvania State University, the United Kingdom Meteorological Office, the University of Cambridge, United Kingdom, the University of Oslo, Norway, Kernforschungsanlage (KFA) in Julich, Federal Republic of Germany, and the Danish Meteorological Institute.

The Arctic Expedition was planned as a follow-on to the Airborne Antarctic Campaign in 1987. Detailed results from that experiment, undertaken to further investigate the Antarctic ozone "hole" first detected by the British Antarctic Survey in 1985, were released in the spring of 1988. Based on those data, a fuller picture of the Antarctic ozone hole has emerged. The findings indicate that:

- Between August and November 1987, column ozone was at its lowest level ever measured at latitudes below 60 degrees south. Ozone levels fluctuated dramatically over large areas in only a day or so, indicating that meteorology plays a critical role in ozone changes in the Antarctic.

- The chemical composition of the Antarctic stratosphere is highly perturbed in the Antarctic compared to elsewhere on the planet. There are differences in the distribution of the chlorine species, in the abundance and distribution of the nitrogen species, and chlorine dioxide levels are highly elevated. In addition, the atmosphere is both denitrified and dehydrated.

Detailed understanding of the exact causal mechanisms will require further analysis. The weight of observational evidence does indicate, however, that both chemical and meteorological processes upset the ozone levels in 1987.

A summary of observations and preliminary findings was issued at the end of the Arctic Expedition on February 17, 1989. The initial observations from this mission add up to a consistent picture that is similar to the one drawn from the Antarctic data in 1987, and are believed to be the result of chemical reactions occurring on the Polar Stratospheric clouds (PSC) that form at cold temperatures. The preliminary results of this mission have substantially increased confidence in scientific understanding of the PSC-induced, chlorine data catalyzed, ozone depletion phenomenon. As a result, it is clear that enhancements of chemically active chlorine components do indeed occur in both the Arctic and Antarctic stratosphere.

BUDGET SUMMARY

Mr. Chairman, I would like to now briefly describe the FY 1990 budget request for Space Science and Applications. The detailed budget, with narratives, has already been submitted. A summary is provided on charts 1 through 3. The total FY 1990 request for Research and Development for the Office of Space Science and Applications is $1,995.3 million. This request will provide the critical support needed to continue our recovery from the Challenger accident, and help return our nation to a preeminent position in the world space science community.

We request $894.5 million for Physics and Astronomy. This will provide for development and operations of the Hubble Space Telescope, to be launched in December 1989, and the Gamma Ray Observatory, to be launched in 1990. This budget line also includes Global Geospace Science, a program managed in our Space Physics Division, and the Explorer Program, which will launch the Cosmic Background Explorer later this year. Continuing funding is also requested for the Advanced X-Ray Astrophysics Facility (AXAF), consistent with Congressional direction on this project.

We request $396.9 million for Planetary Exploration. This will provide the funding required to pursue an excellent planetary program. Our efforts at recovery from the Challenger accident will be rewarded with the 1989 launches and subsequent operations of the Magellan and Galileo spacecraft; the Voyager flyby of Neptune this year is also expected to yield exciting scientific data. The request also supports the continuing development of the joint NASA-European Space Agency Ulysses mission, scheduled for a late 1990 launch, as well as the Mars Observer, scheduled for launch in 1992. Initial funding is requested for the dual Comet Rendezvous Asteroid Flyby (CRAF)-Cassini mission, NASA's highest priority new start. CRAF-Cassini offers an excellent science opportunity with strong international participation, at a cost reduced by the use of common elements.

We request $124.2 million for Life Sciences. This funding will support our systematic build-up to the Space Station era, while maintaining our ongoing programs. Included in this budget are funds for: the Extended Duration Orbiter medical program; definition and development of integrated Spacelab payloads for six missions from FY 1990 to FY 1992; establishing Specialized Centers of Research at selected universities; definition and initial development activities for a 1.8 meter centrifuge facility; continuing work on the exobiology microwave observing project; and planning and research to ensure crew health and safety during future extended Shuttle missions and Space Station assignments. As I mentioned earlier, Mr. Chairman, this program has been carefully developed in response to the recommendations of science advisory groups from inside and outside of NASA.

In the Space Applications budget, we request $434.3 million for Earth Science and Applications. This will continue to support the strong progress we have made in studying the individual components of the Earth, including the interior, crust, biosphere, oceans, ice cover, and atmosphere. It will also allow us to undertake important steps toward developing an understanding of the Earth system as a whole. The budget will support a wide ranging research and analysis program in upper atmospherics, oceanic processes, land processes, and atmospheric dynamics, as well as in areas that cut across these disciplines. The request includes funds for continuing development of the Upper Atmosphere Research Satellite, as well as the joint U.S./French Ocean Topography Experiment. Development of the Scatterometer instrument continues in FY 1989. Following cancellation of the Navy Remote Ocean Sensing Satellite (N-ROSS) which was the original flight opportunity for the Scatterometer; NASA has pursued another potential flight opportunity with the Japanese. The Japanese have made a preliminary selection of the Scatterometer for the ADEOS mission. This selection was made so that the Scatterometer could be included in the ongoing ADEOS Phase B study. Final selection will be made in August 1989 concurrent with final mission approval by NASA.

We request $92.7 million for Materials Processing in Space. These funds will provide for continuing microgravity payload missions on STS, as well as for definition and design work on the six currently envisioned microgravity facilities for the Space Station Freedom.

We request $18.6 million for Space Communications and $34.1 million for Information Systems. In Space Communications, we will continue to support the Satellite Aided Search and Rescue (SARSAT) program, Radio Science and Support Studies, Communications Data Analysis and Advanced Communications

Research. Our request for Information Systems reflects consolidation of networking requirements within the OSSA information systems program, as well as our commitment to prepare for the six-fold increase to data volume expected in the next five years. No funding is requested in FY 1990 for the Advanced Communications Technology Satellite (ACTS) Program, consistent with the position of the Administration to avoid possible competition with the private sector and to minimize government subsidies for activities more appropriately and effectively undertaken by the private sector.

As a whole, this budget request supports a vigorous and balanced Space Science and Applications program. It will continue the critical support needed to carry out the ongoing program, prepare us for an orderly transition to the Space Station, and establish the strong planning base needed for the program of the future.

CONCLUSION

Mr. Chairman, I believe that this budget request is consistent with the requirements for continued U.S. leadership in space science and applications -- a leadership that we can be proud of and a leadership whose merits will be unquestioned. Let us continue to pursue the wonders of the universe both within the confines and beyond the bounds of this planet.

Senator ROCKEFELLER. Dr. Fletcher appeared before this subcommittee, a day or so after the Congressional pay raise was turned down. Most people knew that the Congressmen's pay raise and the judges' pay raise was at stake, but most people did not know that there were 3,000 or so extremely senior civil servants, many of them research scientists, whose pay raises were also at stake, whose salaries depended upon that vote.

And he predicted that he would lose many of the senior research people at NASA. And I was told by a friend of mine at NASA that a lot of that has come true.

Is that the case, Dr. Fisk?

Dr. FISK. I think it is coming true. I think there are two aspects of this problem. One is that there will be retirements, people leaving the government service for industrial jobs and other careers. There was a slight slowdown in that when there was hope for the pay raise, and I think we are starting to see it speed up now as that hope becomes——

Senator ROCKEFELLER. People were hanging on because of the Challenger and their sense of duty?

Dr. FISK. They were hanging on for their sense of duty and they were hanging on for their sense that maybe the pay raise would have occurred.

Senator ROCKEFELLER. Right.

Dr. FISK. And now that that does not seem to be the case, the retirements are starting to pick up.

But the one that bothers me the most is the issue that when these people leave you cannot fill the positions. We have in the

Office of Space Science and Applications alone about ten unfilled positions, that we are simply unable to fill for the lack of an adequate salary.

Senator ROCKEFELLER. Could you run through some of the descriptions of those jobs?

Dr. FISK. You will—for example, I am sure you are going to ask me today about microgravity research. We do not have a permanent director for the division of microgravity and we have not had one for two years.

And so we run this program, which is of national interest, that is of concern to the competitiveness of the country. We are planning all sorts of activities for the Space Station. We run it with temporary people. You may ask me about——

Senator ROCKEFELLER. What does that position pay?

Dr. FISK. $75,000.

Senator ROCKEFELLER. And what would the market pay in which you have to go to compete?

Dr. FISK. The closest I have come is offering it to a person who made a factor of two more, who made $150,000. I even had someone who I was interested in who made a factor of three more. They sort of laugh at that when you ask them to come.

You will probably ask me about Mars Observer as a project. We do not have a permanent project, program manager for Mars Observer project.

We talk about Hubble telescope, for example. We have someone in charge of Hubble, but we were unable to fill the position of the program manager for Hubble from the outside. We had to transfer someone from another project because of the importance of Hubble, but that in turn then left the Explorer program, of which we have a lot of interest and activity in, uncovered with a permanent program manager.

So I mean, from a very real management sense I worry about the fact that programs for which we are responsible and that people expect us to deliver on budgets and schedule and keep them growing, we do not have people in key positions. You get this from—you not only have the inability to hire people from the outside; you have the inability to transfer people within NASA.

The cost of living in Washington is so much higher than it is in Huntsville or at Johnson Space Center that qualified people at the centers that you might like to bring in to headquarters simply cannot make the transition.

Senator ROCKEFELLER. That obviously has to affect your morale. Is that noticeable inside your part of the agency?

Dr. FISK. A lot of us really enjoy what we do, and you know, there is a great challenge and excitement to the space program, particularly since in space science we are going to launch.

I do not have a great sense that a lot of our folks are going to leave, because they enjoy their positions and they enjoy their activities. But as they leave, I am sure I cannot replace them, and that scares me the most.

If you look at the normal kind of turnover rate, typically a division director at NASA might be there five or six years. Most of my division directors have been there about six or seven years now, and so just in the normal evolution of people's careers they may wander off, and I really have great concern that I will be able to replace them with the same quality people.

In my own case, I might add, I have got three kids to educate, and when the second one hits college I suspect I am history at that point, because it is simply not possible to——

Senator **Rockefeller**. The math does not add up for you.

Dr. **Fisk**. It does not.

Senator **Rockefeller**. It will not.

It is an extraordinary problem, is it not, in government? And it is just an amazing fact. And this is no plug for Congressional pay raises. They ought to be totally separated from holding all of you hostage. But it is just amazing, looking at other countries and what they are doing, how we do this to ourselves as a country.

Nobody knows it, of course.

Dr. **Fisk**. That is right. I am amused by your statement. My mother lives in Wisconsin and I was rooting, telling her to, write your Congressman, you know, vote the pay raise. And she said: Well, why? I mean, they do not deserve a pay raise. And I said: I deserve the pay raise. And she said: I did not know you were coupled to that.

Senator **Rockefeller**. Yes. The fiscal year 1990 budget proposes two new starts in space science, the CRAF-Cassini mission, and two terminations, the Advanced Communication Technology Satellite, the ACTS program, in space applications, and Gravity Probe B in space science.

Dr. Fisk, in light of the severe budget pressures facing NASA, why should the Congress grant new start status to the CRAF-Cassini missions? What is the scientific value of these missions, and what level of foreign involvement and financial participation are there in each of these missions?

Dr. **Fisk**. Okay, let me deal with that in some detail. We seem to get excited each year by the magnitude of our new starts. We talk about the fact that a new start is somehow an event that requires a great deal of concern and consideration.

I almost wish we could get over that issue, because space science, we are launching this year and we are going to launch every year. And if you want a space science program with a continual level of activity, every time you launch something you ought to be starting something new, so that there is a steady state of activity that occurs.

We try each year to begin a new program. We began AXAF last year, we began GGS the previous year. And you would like to be able to do that, one major new program each year to replace the major new programs that are in fact launched.

And in fact if you ask that question from a budget point of view and you say, well, if that is a good theory, then in principle the budget should not grow out of bounds, because you are in fact starting a new program. And that is in fact the case with the CRAF-Cassini mission, that because we are launching things and are development costs are therefore stopping for certain projects, that the budget for space science and applications in 1991, 1992, and 1993, based on the 1990 budget, does not grow faster than inflation.

So that the cost of doing a CRAF-Cassini mission fits in a wedge that opens up as a result of the beginning launching of new programs.

Now, as for the merits of the program itself, the CRAF-Cassini mission is a very fundamental mission. It asks the question, from whence did we come? There are three things we ought to know if we want to understand essentially the origin of life.

We want to understand the original material from which the solar system was formed. Now, the Earth is not a good example of that because there has been so much processing of material here and all the volatile gases escaped. We are too close to the sun.

If we want to know the original material from which the solar system formed, we have to go into the outer solar system, where the material is essentially unaltered by the Sun's heat and radiation like Saturn, or comets.

The other question we need to ask is what is the material from which life formed on the Earth, and there is some speculation, some good speculation, that the organic material, the carbon-based material that gave rise to life, did not originate here on the Earth, that there was not enough of that material present, and that it was brought here by comets striking the Earth.

And so one of the things we want to understand is the actual composition of comets, because that may be the material from which life formed on the Earth.

And the third point is that, the material have gotten here, we need to understand the chemistry which gave rise to life. And again, today's Earth is much different from the primordial Earth, but there is a satellite of Saturn called Titan which has chemistry on it which is believed to be very similar to the chemistry that occurred in the early Earth.

So you go out and you look at what is actually happening on Titan. It is colder on Titan, things are moving slower, and as a result the chemistry that may exist on Titan today is the same chemistry that may have existed in the early Earth a long time ago, and you can understand the chemical reactions.

So the combined mission, CRAF to a comet, Cassini to Saturn, with probes into the nucleus of the comet, probes into Titan, a satellite of Saturn, gives you basic answers to those three questions: What was the original solar system made of, what was the material that gave rise to life on the Earth, and what was the chemistry that processed that material perhaps into life.

The other point I need to make too is that this is a perishable opportunity. Celestial mechanics is changing. Remember the old grand tour. When that was considered by the Congress, one of the compelling arguments for doing it was that the planets lined up in only a certain way at a certain period of time which allowed you to go from Earth to Jupiter to Saturn to Uranus and Neptune.

Well, that alignment is changing, so that to get to Saturn at the end of the century, Jupiter will no longer be in a position to give you a gravity assist and the trip time goes way up.

The same thing happens for the comet mission. The absence of a powerful upper stage for planetary missions these days means that if you want to get to a comet you have got to go first to Venus, get a little gravity assist, and then you fly out and rendezvous with a comet.

Well, the opportunities to do that depend on the alignment of the comet and Venus and the Earth. And the opportunities do not exist at the end of the century for being able to do that in a reasonable trip time. So we are either going to start CRAF-Cassini this year or we are not going to start her for a long time.

So there is a compelling need to get this going at this time.

Senator ROCKEFELLER. So that would be your first priority?

Dr. FISK. Absolutely.

Senator ROCKEFELLER. Why was the Gravity Probe B program terminated? And what would it cost to complete the development of the Gravity Probe B instrument and to do a Space Shuttle test in 1993? Was this option assessed?

If NASA cannot afford to fund Gravity Probe B that costs $300 million, how can NASA afford to initiate the CRAF-Cassini missions that you have spoken stirringly about, or the Earth Observing System, that each cost $2 billion?

Dr. FISK. I need to get on the record here some really important distinctions. Gravity Probe B is not what was cancelled. Gravity Probe B would be a free-flying spacecraft mission to do these fundamental tests of relativity, but it is a new start someplace in the future.

And in order to have that new start, we would have required permission from OMB, from the NASA Administrator, and brought it forth to Congress, as we are bringing CRAF-Cassini forward this year. And according to our strategic plan, it is a new start that could occur in the 1993–94 time frame, someplace out in that time frame.

What we cancelled was an advanced technology development program which would have permitted Gravity Probe B to occur, and that program we label STORE. It is called the Shuttle Test of Relativity Experiment. That was the $25 million cut in the program.

But it is an ATD program, an advanced technology development program. Now, unfortunately, in cancelling it that precludes your ever doing Gravity Probe B at some point in the future.

So to compare the cancellation of STORE to CRAF-Cassini is not a good comparison, because CRAF-Cassini is our highest priority new start this year and it would be followed hopefully next year by a new start for the Earth Observing System, and perhaps in future years by a new start for the infrared telescope facility, and someplace downstream there would have been a new start for Gravity Probe B.

Perhaps the better comparison to make is against other advanced technology development funds that we have in the budget. And we had to make a priority decision on that point, because we have, for example, $25 million in the budget for the advanced technology development for the Earth Observing System.

And so you could say, how would you make a priority decision between the $25 million we were going to spend on STORE, leading to Gravity Probe B, versus the $25 million we are going to spend on EOS, leading to its new start? Well, the EOS new start is the highest priority next new start in 1991 and the GPB new start is downstream someplace, and when we had to make that trade we chose to give the priority to the advanced technology development funds for EOS.

But CRAF-Cassini has a much higher priority in the budget because it is this year's new start, it is not a new start someplace down in the future here.

Have I made myself at all clear? I have been bothered a bit by some of the comparisons that are made between say a new start CRAF-Cassini and STORE-GPB, because GPB is not a new start this year and, according to our strategic plan, it had a lower priority as a new start than does CRAF-Cassini or EOS or those things.

And so in evaluating our needs, we reduced the advanced technology development funds that would lead to that new start because of its priority in the queue for new starts.

Senator ROCKEFELLER. Is not Gravity Probe B strongly endorsed by the scientific community and a very good example of university and private sector cooperation?

Dr. FISK. Mr. Chairman, it is an excellent program, and it pained me greatly to have to reduce those ATD funds, because it is an excellent program. It is exciting science. It is an excellent example of university-industry cooperation.

It is one in which I have a lot of promise—a lot of potential, for which there is a lot of potential for some very exciting science. But when we evaluated our priorities—and we really do take our strategic plan literally, and when we had to make a $25 million cut in the budget at the last moment, we looked at that and said which priority—which new start has the least priority, GPB had it.

And so you back up and say, which advanced technology development funds are therefore most vulnerable, and that was STORE.

Senator ROCKEFELLER. And that was it.

Senator Bryan, incidentally, just interrupt me at any point, because I will just wander on. We have no rules around here.

Dr. FISK. How much funding would be required in fiscal 1990 to finish the Advanced Communications Technology satellite, and to ensure its launch in 1992? And why was it that OMB deleted funding for the last installment of this spacecraft, since we have already appropriated over $434 million for ACTS?

Dr. FISK. The funding in fiscal year 1990 is $62 million in my recollection, and the 1991 funding is $34 million. And they cancelled it this year for the same reasons they have cancelled it every previous year. This is a policy issue with OMB that says that this is better funded by the private sector, and I cannot defend it beyond that point.

Senator ROCKEFELLER. I understand that.

Materials processing and life sciences as you know and as you indicated are areas that I am very interested in. And I do, whether I am totally right or totally wrong, believe that the cure for cancer is up there in zero gravity, and that the cure for diabetes may be there, too.

And that strikes me as an extraordinarily high priority for the nation, and therefore I am obviously interested in seeing these activities expanded.

What type of flight programs do you currently have planned for materials processing and for life sciences? And do you have the budget and the hardware required to do what you would like to do for an aggressive program?

Dr. FISK. Let me talk about this for just a moment. I think we have under way now, and again as a result of strategic planning activities and a number of activities over the last two years, a very systematic program in both materials science and life sciences.

There are three Spacelab series: one called USML—U.S. Microgravity Lab; IML, the International Microgravity Lab; and SLS, the Space Life Science Series. And they begin in 1990 with the first flight of SLS-1, and there are Spacelab series on—each of them runs on a 15-month center, and so you get between two and three Spacelab flights per year.

The USML is devoted exclusively to materials research, materials and fluids research in space, the SLS is exclusively life science, and the IML is a combination of the two.

And so we have a regular series of Spacelab flights which will proceed between now and Space Station. The plan is to use those flights to both develop the—to do the research and the science, but also to develop the equipment that will ultimately be ready for Space Station. So we will build, test, revise, upgrade, and improve facilities systematically between today or the first flight of SLS-1 and the Space Station.

So when Space Station comes, we simply transition these facilities from the Spacelab series to the Space Station. That is about as high a flight rate as we can maintain in these fields for the amount of equipment we have. We are essentially turning the Spacelab hardware around as fast as it is humanly possible to turn it around. And so I think we have the right flight rate in the program.

We also have now a commitment to go forward with the EDO. There will be a 16-day EDO, Extended Duration Orbiter, on Orbiter 102, and 105. The new Orbiter will be scarred for anywhere from 16- to 28-day flights, and that not only gives us a regular series of Spacelab flights, but also a series of considerable duration.

Now, in regards to the funding, the materials research budgets at the moment are adequate. However, they are tight. We may have to look at them in the out years to make sure that they are still okay.

We are developing all new hardware, and any time you develop new hardware you experience some challenges in this. So I am sure the budget in 1990 is fine. We are going to continue to look at the budgets in 1991 and 1992.

In the case of life science, the 1990 budget supports the definition of the equipment that will be transitioned through Spacelab to Space Station, but it does not actually start the hardware line.

We suffered quite a setback last year. You will recall that we proposed in the 1989 budget a substantial augmentation for life science and $25 million of it disappeared in the Congressional budget process. And that essentially delayed us a year.

The original intention was to do the program definition for life sciences in this fiscal year, in 1989, and to begin the hardware development in the 1990 budget. Well, now we will do the definition in 1990 and begin the hardware development in 1991.

We will still have everything under way for Space Station. We have essentially four Spacelab flights between now and the nominal beginning of the assembly of Space Station, and so we will use those flights to be able to test the facilities and have them ready in time for the Space Station.

So I think our plans are in good shape. Our budget is realistic in 1990. In 1991 we will perhaps have some challenges to the materials science budget and we will want to initiate the life science activities.

Senator ROCKEFELLER. That is good news.

Senator Bryan.

Senator BRYAN. Thank you very much, Mr. Chairman.

Dr. Fisk, I would like to follow up on an inquiry that Chairman Rockefeller began, namely the critical shortages of top-level technical positions. And my question is this: So often as we are asked to consider issues that deal with pay raises, we are talking about a comprehensive, across the board pay raise.

And as the chairman observed, the Congress was included in the last one, I think inappropriately, and I agree with him we ought to separate those.

But my question is this: Is there a plan being developed within the Administration to identify those categories, not by GS level but by occupational description, in which there are critical shortages, so that the Congress might consider with respect to those individual positions an augmentation that would be separate and apart from any other general, across-the-board pay raise, or cost of living adjustment that might be made for the civil service generally?

Dr. FISK. Let me ask Ms. Schmoll.

Ms. SCHMOLL. There are some activities within the Administration and ongoing within NASA to identify the current critical shortages, but I think more importantly, Senator, the future shortages.

Senator BRYAN. Ms. Schmoll, if that list becomes available, I certainly do not mean to speak for the chairman, but I am certainly speaking for this member, it would be very important, because I think that is something that we can sell to the American public as being in the national interest.

It is very difficult for us to return to our respective states and talk about the budget deficit, which is hundreds of billions of dollars annually in terms of real deficit, as opposed to the convoluted method by which we developed the Gramm-Rudman-Hollings formula, and then talk about 20 percent pay increases across the board or 51 percent pay increases.

But if we can identify those critical areas in which there are shortages, I think a more persuasive argument can be made and I for one would be willing to consider that.

Ms. SCHMOLL. Senator, there is one thing that I think is important to keep in mind, and that is that that pay raise was aimed at the Senior Executive Service. And all of the people, all of the positions that Dr. Fisk mentioned that are vacant, are in the Senior Executive Service.

So I think that it is not only just having a physicist or an engineer, but it is one who has some managerial and executive capabilities.

Senator **Bryan**. Understand the point that I was trying to make is, rather than a categorical, across the board, we need everybody at this GS level to get a 20 percent increase, to identify within that Senior Executive Service those areas that we are having difficulty in recruitment for.

And if that is going to be made available, I would appreciate it.

Ms. **Schmoll**. Yes, sir.

[The following information was subsequently received for the record:]

The critical shortage of top-level technical positions, and qualified people to fill those positions, has been a long-standing concern at NASA in general and the Office of Space Science and Applications in particular. Increasingly, we are finding that highly skilled, qualified employees are leaving the Agency in most part because the wages they can command in private industry are two to three times higher.

To address this crucial issue, NASA has begun an institutional strategic planning process to look at ways that we can, not only retain the skilled labor that we have, but also attract new and brilliant talent. We currently have an Institutional Strategic Planning Steering Committee composed of top-level managers from NASA Headquarters and the Centers to evaluate the current status of the institutions and to make strong recommendations for its direction in the future. The issues and concerns this Committee will address include: Assess macro institutional needs and capabilities, identify institutional issues in the context of agency plans and direction, particularly in regards to personnel, and identify institutional implications throught the NASA strategic planning process.

The Committee plans to issue a report of its findings and recommendations sometime in late summer or early fall of 1989. We will be pleased to inform you of the Committee's assessment at that time.

Senator **Bryan**. Dr. Fisk, returning, let me talk about the other end of the pipeline, which is of concern to me as well. I recall Dr. Fletcher's testimony, as does the chairman. He indicated about 45 percent of the agency's technical staff would be eligible for retirement within the next 18 months, if I recall that testimony accurately.

My concern is in terms of what we are doing to attract high school students and students at the university level to get involved in the technical fields which you need and which are so important to the development of your program. I am concerned about what we are doing to encourage those undergraduates who have chosen technical fields in engineering or space science to go on to the graduate level and get master's and doctoral degrees.

We just dedicated a new School of Engineering at the University of Nevada-Las Vegas over the weekend, and one thing that struck me is that when you are talking about conferring doctoral degrees in this country in engineering fields today, nearly a majority of those doctoral degrees are being conferred upon students who have come from abroad to study in America and who will, after receiving that graduate degree, return to their homes.

And I see that as a major concern. Could you address that and what we need to do, if anything?

Dr. **Fisk**. I think you are raising a very real concern. Let me say how I personally think we ought to deal with this and also some of the very specific things we are doing.

As much as any, we have to be concerned with the motivation of people to go into science and engineering. We have to convey a degree of excitement, of the career opportunities, of the enjoyment that they would have for being involved in these kinds of fields.

And people tell us that we have to go back to grade school, to the secondary schools, in order to be able to get that excitement.

And I mean, I have some very real worries about our being able to do that or the consequences if we do not do that, because first of all we are seeing major demographic changes in the country. The number of secondary students that will be from minorities is going up on a percentage basis. Historically, they have not gone into science and engineering. We have to change the attitude that says this is an exciting thing to be able to do.

In my judgment the space program and the activity that it generates, the visibility, is one of the key ways to be able to do that. We will launch 35 times over the next five years. Each one will be a major event. It is a Magellan, it is a Hubble, it is a Galileo.

NASA is pretty good at getting the word out that this is an exciting thing to happen. 400,000 people go to the landings, 500,000 people go to the launches. And we make a major effort in being able to publicize the fact that this is exciting science and there is exciting and interesting engineers working on it.

And I think that that activity level is important, because the space program is probably the most visible science that people do.

Now, in terms of specifics, one of the things that is going to happen with these 35 launches is there is a lot of data coming down. I mean, there is an enormous amount of space science data that is going to come down in the next five years.

And we are busy planning for how to handle that data and talking about how we are going to be recruiting people to come into space science and join with us in the analysis of this data.

We started a small project the other day, with which I am really pleased. It is called JOVE, and it stands for Joint Venture in Education, because we looked at and we said, gee, there are an awful lot of universities out there that do not get involved in the space program. You know, space science is only done at a selected number of universities.

And one way to sort of spread the involvement in space science is to reach out to some universities that are not currently involved in space science. And we started a pilot project in which we establish a mentor at a NASA center, we ship data to these universities, and they in turn get their faculties involved in the analysis of that data.

And the quid pro quo is not only do they provide the faculty time—we provide the data, the smart terminals and the mentor, they provide the faculty time. But in addition to that, they have to reach out into the secondary schools and get some secondary students involved in the analysis of that data.

And I think it is an interesting project to try and use the availability of all this new science data coming down to involve people that are not now involved in space research, get them involved in the program, and in turn have them reach out to the secondary schools to stimulate the students to be involved in science.

It is not a large project, but I think it has a lot of potential. In fact, I might point out there is one in the University of West Virginia that just started out.

Senator BRYAN. I would hope that the University of Nevada might be considered as well, Dr. Fisk.

Dr. **Fisk**. Make a note.

Senator **Bryan**. I have one last question, if the chairman will indulge me. And that is, this is a real softball, but with all the budget constraints that we face and all the tough policy choices that we have to make or that we should be making, what do we tell the American people?

Why should we be increasing your budget 9 percent this year and the overall space budget by several billions of dollars? What benefits do the American people derive from the space program? And again, I am not discounting the scientific analysis that you have just indicated in terms of the origin of life and the chemistry that was involved in that evolution.

But in language that is the idiom of the street, what do we tell the American people?

Dr. **Fisk**. Well, let me answer it in a couple of ways. We can always tell the American people, correctly, about the spinoffs that come from space, the fact that we are going to provide research that can lead to cures of major diseases and there are new technologies that come out of it. And the American public I think sees that in their everyday life, and you can point out case by case, whether it is a pacemaker, whether it is some other medical device, that it had its origins in the space program.

I guess personally I always prefer the more fundamental one, that says that when you have an active space program you send a very clear simple message that says you are a nation that believes in the future.

I think that probably government has one principal responsibility, and that is to convince the public that tomorrow is a brighter place, because if you do that you get motivation, you get ambition, you get perseverance, you get accomplishment out of the people. They believe that tomorrow is going to be a better place.

The space program is really that investment. You are investing in tomorrow. You are investing in not only basic research that leads to basic, new technologies. You are investing in new frontiers that the country needs to be opened up. And you are investing in the youth, because you are giving them some stimulation of an excitement and things to look forward to.

I guess, you know, we have a lot of budget troubles. We have big defense needs, we have concerns over the homeless and the poor. In many ways those are expenditures that are based on fear and on injustice, and somewhere among that there should also be some expenditures that are based on hope.

Senator **Bryan**. That is an excellent answer.

Thank you very much, Mr. Chairman.

Senator **Rockefeller**. Thank you, Senator Bryan.

Senator Danforth, do you have any?

Senator **Danforth**. Yes, I do, Mr. Chairman. Thank you.

Dr. Fisk, when Jim Beggs was the Administrator of NASA he told me one time that NASA was going to put into space a telescope. He said that heretofore telescopes have had the problem of atmospheric distortion and that this telescope was going to be just remarkable because it would be possible to look through the telescope—I could be wrong because I am not a scientist, but this is the gist of what he told me. He said that one could look through the telescope and see out, I think he said, 15 million light-years. And he said a lot of scientists believe that the creation of the universe was by the Big Bang and that that would be visible through this telescope.

So it would be conceivable that by looking through this telescope we could see creation. That was a very startling revelation, I thought. I immediately began telling people about this wondrous thing that I had been told, and people said, no, that cannot possibly be.

So the next time I saw Jim Beggs I said: Look, let me see if I have this straight; you can look through this telescope——

Dr. **Fisk**. Those people were from Missouri, I assume?

Senator **Danforth**. That is right.

You could look through this telescope and you could see creation? And he said: Yes, or close to it. And he said: The one thing we do know is that whatever we can see is going to be so startling that we just could not imagine it.

Then we had the tragic Space Shuttle disaster and the space program was set back. It is my understanding that—am I right in thinking that the day is upon us when this telescope is going to be put in space? And could you describe to——

Senator **Rockefeller**. To a minister.

Senator **Danforth**. [continuing]. Those of us who are incredulous folk, what is this thing? What will we be looking at? Beggs thought that this really was one of the most exciting advances in the history of science.

Dr. **Fisk**. I think it is exactly that. It is the Hubble space telescope. It will be launched in December. December 15th is the scheduled launch date.

Now, you are off by a factor of a thousand. It is 15 billion light-years out there.

Let me give you a short course in astronomy here. The universe is believed to have started in a Big Bang, and that is a gigantic explosion somewhere around 15 to 17 billion years ago.

Shortly after the explosion took place, there was a certain kind of radiation that was given off, and that radiation is still out there and it is called the background radiation for the universe. There is a satellite called COBE which will be launched in July or August of this year which will observe that.

Then after the universe settled down a bit after this explosion, it started to form galaxies and stars and other things like that. And they are out there at about—that occurred say within the first billion years of the formation of the universe, and so the light that came from those galaxies has been traveling for 15 or 16 billion years to get here. And it has gone 15 or 16 billion light-years, the distance light goes in a year.

Now, the Hubble space telescope can see about a factor of ten deeper into the universe than any previous telescope has been able to see. So it can see those objects which were first formed right after the universe started to settle down and begin to form stars and galaxies.

So it will see galaxies and stars at the very beginning of time, and that is something you cannot do from the ground. You can only do it from space.

It is important to note, by the way, that there is not only the Hubble space telescope about to be launched, but the Gamma Ray Observatory observes the universe in very high energy radiation called gamma rays, with resolution many times more than anything we have done before.

Last year's new start, the Advanced X-ray Astrophysics Facility, will observe the universe in X-rays in a resolution close to a factor of a thousand more than anything we have done before.

And somewhere in the future we would like to do the Space Infra-Red Telescope Facility, which observes the universe in infrared radiation at about a factor of a thousand more than we have done before.

When you put that flotilla of four great observatories up—Hubble, Gamma Ray Observatory, Advanced X-ray Facility, and Space Infrared Telescope Facility—you essentially observe the universe in every radiation, every important radiation that comes to us from the universe.

My guess is it is a revolution in astronomy waiting to happen, and probably comparable to the kind of revolution that occurred when Copernicus decided that the Earth was not the center of the universe, that the Earth in fact went around the sun.

The kind of revolution in thinking that will come from this revolution in observations is going to be profound in a way that has not occurred in hundreds of years.

Senator DANFORTH. Amazing changes in our way of looking at the universe.

Dr. FISK. Absolutely.

Senator DANFORTH. When will this happen? You said that the Hubble telescope is going to be deployed in December, but is there a time lag, or on December 15th do we immediately have this new view of the world?

I mean, when do we wait to be shocked?

Dr. FISK. I think the shocks come continuously. We will put it up and then we will learn to use it. I mean, it is a tremendously powerful instrument, and as a result the data coming down from it—you know, we will learn to steer the thing and learn to point the thing and learn to handle the data as it comes down.

But within months of its going up, you will begin to see exciting new observations. And in fact, like all good scientists, they are going to point at the most interesting objects first, you know, the most interesting part of the universe.

So I expect new wonders to come down very quickly. But it is important to realize that we are planning to keep that on orbit for 15 to 20 years, that one of the advantages you get with the Space Shuttle is you get to put this on orbit and you get to maintain it on orbit.

So this instrument, Hubble, and AXAF after it and GRO and SIRTF, these are all instruments which will have a long life on orbit, and we will be able to essentially have a 15- or 20-year period when we will be able to use these instruments to understand the universe in ways we have never had before.

Senator DANFORTH. Give us the timetable. You said one is going up in December and one is going up earlier than that?

Dr. Fisk. No. Hubble goes up in December. The Gamma Ray Observatory is manifested in April of 1990. The Advanced X-ray Astrophysics Facility was a new start last year. It is a 1995 launch. And Space Infra-Red Telescope Facility could be a new start in 1992 or 1993, and about a 1997 launch.

So by the end of the century, all four of them are working simultaneously and, as you say, opening up a revolution in astrophysics.

Senator Danforth. Is there anything more that you care to add about this? I mean, is there anything else that would blow our minds?

Dr. Fisk. Well, I think one thing I would add on this thing is that it is important to realize that those facilities have no rivals in the world, that no other space program is in a position to put up these kinds of instruments, either for their power as telescopes and observatories or to use the shuttle facilities to be able to maintain them on orbit.

So basically, in some ways it will be in the 1990's as if the United States is the only astronomers with telescopes, because our telescopes will be so much more powerful than anybody else's.

Senator Danforth. Let me ask a question that Senator Bryan asked. Is this a matter of pure science plus a little national pride, or is this something that Joe Blokes is going to benefit from?

Dr. Fisk. Well, I think it is pure science, national pride, and the benefits come in a variety of ways. There are the benefits of the technology that you have to develop in order to be able to do this.

There are techniques using the X-ray mirrors on AXAF, for example, which have some interesting applications in making high-density circuit boards. You run your X-ray telescope backwards and you can do—I do not even remember the name of the technique, but essentially you run it backwards and you can do etching with X-rays on things in a density you cannot do otherwise.

So there are these kinds of benefits that come from the technology. But one of the things, it is important to realize that if you want technology in the twenty-first century, it is going to be based on basic research that occurred in the twentieth century.

One of the basic researches that comes from astrophysics is that you test the laws of physics. You have to realize that we know enough about physics these days that it is very hard to provide in a laboratory the kinds of extreme conditions that determine whether the laws of physics as we understand them are correct.

We cannot get densities much higher than we currently can achieve. We cannot get stronger magnetic fields than we currently get.

So you go off into astrophysical settings, where there are neutron stars and quasars and you have magnetic fields and densities well beyond anything you could achieve in a laboratory. You see how the laws of physics work there and then, based on that understanding, you get a new appreciation, a new in-depth understanding, of the laws of physics, which have some very real applications after that.

So astrophysics is kind of the forefront of physics, because it tests the laws of physics in conditions we cannot get on the Earth.

Senator Danforth. Well, I think it is remarkable, really very, very exciting. And I hope NASA will come back as this evolves and describe to us in terms that even the densest of us, meaning myself as far as this kind of thing is concerned, can understand.

Dr. **Fisk**. I am looking forward to my testimony next year. I had to testify twice with no satellite launches behind me. So next year I am planning to come back and show pictures and tell you what we have done.

Senator **Rockefeller**. Well, I hope you are still here, that your daughter has not gone to college.

Senator Danforth, that was a point that Dr. Fisk made earlier. Remember when Jim Fletcher came in after the pay raise did not go through and said that they would be losing many of his top people because of the 3,000 Senior Service that nobody knew about.

Senator **Danforth**. Right.

Senator **Rockefeller**. And Dr. Fisk has indicated that is beginning to happen and would in fact even affect him at the point that his daughter, I believe that it was——

Dr. **Fisk**. Son.

Senator **Rockefeller**. Son, the second one, would have to go to college.

Senator **Danforth**. Could I ask about that? I appreciate that. Reading the morning paper, apparently the President is going to suggest a 25- or 30-percent increase for scientists and judges and other people in the administration.

What would it take in your opinion, what kind of pay raise would it take, for NASA to be able to attract and retain the kind of people that it needs?

Dr. **Fisk**. Well, I think I am interested in what you read in the paper. I was not sure from what I read in the paper this morning it was not just judges, but I am not sure. I hope it includes the SES.

If I look at the experience, I was citing for the chairman the experience in trying to recruit a director for the microgravity research program, and the closest I came was someone who made about a factor of two more than the existing government salaries.

But I had a sense in that discussion that, because of the excitement, the interest in the program, the ability to actually do something, that people were willing to make sacrifices to come work for the government. It is just that a factor of two is too far a sacrifice for anyone to make, given the standard of living to which they were accustomed.

My guess is that 25 percent will make a big difference, because it would show faith, it would show that people recognize that this is a real problem. Fifty percent would actually—in time would be sufficiently close to the kinds of salaries that people would not consider it to be an enormous sacrifice to come out of the private sector.

Senator **Danforth**. Thank you.

Senator **Rockefeller**. I think that is very valid. It is not that the salaries have to be competitive or even in fact have to be close to being competitive. But the Federal government has to be showing that it is making an effort and that we are not bashing people around the walls, but trying to honor service at high levels. It is a rather basic concept to the progress of nations, it would seem to me.

I want to return from the sublime to my usual line of questioning. There was, as you know, recently quite a lot of publicity about a radio telescope that had collapsed in West Virginia, and that was a very basic 300-foot radio telescope that the National Radio Astronomy Observatory at Greenbank, West Virginia, had been operating for a consortium of universities and the National Science Foundation.

And there has been some discussion about how it should be replaced. Senator Byrd and I have been accused of pork-barreling.

Senator **Danforth**. No.

Senator **Rockefeller**. But not by the scientific community, and surely not by the radio astronomers. We envision the replacement of that scope with a modern, fully steerable telescope in the 100-meter diameter class. It would be capable of operations at all wavelengths between about ten meters and fractions of a centimeter.

And I might say, incidentally, that scientists come from all over the world to Greenbank to be able to use this radio telescope as it existed, from all over the world all the time.

At most of these wavelengths, the telescope's performance would exceed that of any other steerable telescope in the world. Dr. Sealstatt, who is the director at Greenbank, pointed out to me that the proposed replacement telescope will present new opportunities for joint projects with NASA in the areas of space-Earth very long baseline interferometry, which I understand is the study of energy emitting from quasars and radio galaxies.

And incidentally, they presented a photograph, Senator Danforth, of a galaxy taken through this telescope, please note that they found not a thousand points of light, but hundreds of thousands of points of light that are photographed and are presented to us in photograph form. These explosions of light happened billions of years ago, and it has taken that long to get to the camera film, which is to me kind of a mysticism of its own.

And also, this telescope is used for deep space probes, receiving signals from probes, and planetary radar, exploring the solar system by receiving microwave signals that have been bounced off of planets.

My question is, would you agree that these are areas that hold strong opportunities for joint NASA-Greenbank, NASA/National Radio Astronomy Observatory cooperation? Do you have any plans to pursue these kinds of projects with Greenbank once the new telescope is completed? I believe the telescope will be completed within three or four years, which may make it difficult for you to answer.

Do you know of any other opportunities beside the projects that Dr. Sealstatt has suggested which could increase cooperation between NASA and the National Radio Observatory at Greenbank, West Virginia?

Dr. **Fisk**. Let me answer in a couple of ways. I pointed out, in response to Senator Danforth's question, that we are flying four great observatories in Hubble and X-rays, AXAF, and SIRTF, Space Infra-Red Telescope Facility, and GRO, the Gamma Ray Observatory.

Now, those all observe in wavelengths that you can only see from space effectively. Gamma rays do not get to the ground, X-rays do not get to the ground, only certain narrow regions of infra-red get to the ground, and the visible is distorted somewhat by the atmosphere.

However, there is a major wavelength band which does get to the ground, which is radio astronomy. So the bulk of radio astronomy is always done from telescopes like at Greenbank.

So if you then combine the observations in the radio region that Greenbank can do and the VLBA and the VLA and all these other things that are out there do with the great observatories that NASA will fly, you have essentially covered the complete electromagnetic spectrum from the longest wavelengths to the shortest wavelengths.

I think that as part of our revolution in astronomy and astrophysics, that we will open up through the new observations from space, together with these powerful radio telescopes—there is sort of nothing we cannot see then. We have covered all the wavelength region.

Now, as for very long baseline astronomy from space, I think the cooperation there is going to be in part with NASA, but also in part with our international partners. The Japanese have a project called VSOP and the Soviets have a project called Radio Astron, which are satellites to do the measurements from space.

Together with facilities like Greenbank and DSN, the Deep Space Network which NASA runs, you provide the ground-based observations that correlate with those space-based observations, and you do get substantially increased resolution by the long baseline that you get from space. So I think it will be sort of a NASA-Greenbank project cooperation, together with the Japanese and the Soviets.

Senator **Rockefeller**. What about planetary radar?

Dr. **Fisk**. Planetary radar I think is a very useful thing, although my own preference is to go to the planet, and I think that to some extent the planet radar projects will be diminished somewhat.

One of the principal planetary radar activities has been looking at Venus, for example. But the Magellan project, where we actually take the radar instrument to Venus with substantially increase resolution, I mean orders and orders of magnitude, may reduce some of the necessity for those projects.

And I am personally not familiar with whether they can do radar in the outer planets. That may be powerful enough to do that. I simply do not know.

Senator **Rockefeller**. I have a number of questions that I will submit to you on behalf of Senator Gore, including some on microgravity. You also would do me a favor if you would get an answer to a question that is not in your section. I have a question for the Office of Commercial Programs and Jim Rose I think would better be able to answer, but he is not going to testify until mid-May.

My question concerns a proposed NASA Technology Transfer Center and there is a possibility of that Center being placed at Wheeling College, West Virginia. I expect you to know none of this. I simply, I would like you to get a response for me from Jim Rose at some point.

It is approximately a $4 million expenditure. It reflects a five-year master plan for the establishment of a national repository for Federal research and development technology transfer.

It has been initiated on the House side. It will be further initiated on this side. I would be interested in NASA's genuine thoughts about it.

Dr. **Fisk**. I would be happy to answer for the record on it.

Senator **Rockefeller**. I hope that your son gets into the college of his choice. If he is anything like his father, he ought to.

And I hope you will be here to testify in years to come.

Dr. **Fisk**. Thank you very much.

Senator **Rockefeller**. Thank you.

[The following information was subsequently received for the record:]

Responses to written questions submitted by Chrm. Gore.

Budget Outlook

The current NASA budget request assumes a substantial funding increase in FY 1990, $2.4 billion over the baseline of $10.9 billion in FY 1989, and additional increases in the outyears. The Office of Space Science and Applications also assumes increases each year although not as large in percentage terms as the proposed growth in the NASA budget.

Question 1: Dr. Fisk, I understand that the participants in the current budget discussion are considering a freeze at the FY 1989 levels for all programs. What would be the effect of a freeze that the FY 1989 budget level for the NASA Space Science and Applications program? And how would you prioritize your programmatic activities if such a freeze were instituted by Congress?

Answer 1: A freeze on the budget at the FY 1989 level would mean curtailing the Space Science and Applications program at a time when we are returning to space and reemerging as a space faring leader after a long hiatus. The increase in the budget supports the new start of CRAF-Cassini, a planetary mission that is critical to our understanding of the origin of our solar system and life on Earth, the timing of which is critical because of limited launch opportunities. The augmentations called for in the FY 1990 budget also include much needed increases to the mission operations and data analysis areas of our budget. The strength of this area will be vital in the near future to enable us to analyze and interpret the data we will gather from the missions launched this year alone.

In terms of priorities, the Office of Space Science and Applications (OSSA) Strategic Plan calls first for the completion of the ongoing program. A freeze would require slipping the development milestones and launch dates of any number of missions, or require an outright cancellation of some part of the current science and applications program without adding any new activities. It must also be noted that without new starts such as CRAF-Cassini, our ongoing program will be severely diminished in the next three to five years.

Question 2: Dr. Fisk, am I correct that pursuant to your strategic plan, last in is first out and any reduction to the Office of Space Science and Applications FY 1990 Budget Request would result in the termination of the proposed new start for the CRAF-Cassini mission because ongoing programs are higher priority?

Answer 2: As mentioned above, the completion of the ongoing program in a timely manner receives top priority in the Office of Space Science and Applications Strategic Plan. However, terminating the new start of CRAF-Cassini would require careful consideration of the perishable launch opportunities and many other elements before a decision could be made. Again, I cannot emphasize enough the importance of this mission to the planetary goals of the Office of Space Science and Applications, and the importance of its timing in this year's budget. As was the case with the unfortunate cancellation of the Shuttle Test of Relativity Experiment (STORE) advanced technology development activity, we would have to look at other elements of our program which may be at a lower priority than the next major space science mission.

Question 3: What additional FY 1990 activities were included in your budget to OMB and why were these programs deleted from the final budget submission? Was it NASA or OMB that deleted funding for the Earth Probes program, the Gravity Probe B space shuttle experiment, and the Advanced Communications Technology Satellite?

Answer 3: The Earth Probes program was deferred by OMB from the FY 1990 budget as a potential new start because of funding constraints. The program is being considered again for the FY 1991 budget as a potential new start.

The Gravity Probe B (GP-B) program was a potential new start according to the Space Science and Applications Strategic Plan in the 1993-1994 time frame, at the earliest. The program that was deleted from the budget was the Shuttle Test of Relativity Experiment (STORE), the advanced technology development program which must precede GP-B. NASA made this decision in response to a general budget reduction imposed by OMB. Given its relatively high FY 1990 cost ($25 million) compared to the likelihood of a GP-B new start in the mid-1990s, STORE had a lower priority compared to other ongoing activities.

According to a long-standing policy of the Administration to move as much commercially relevant technology as possible to the private sector, the ACTS funding was deleted by OMB from the NASA budget as in every previous year.

Question 4: Dr. Fisk, what level of funding is required by the Office of Space Science and Applications to support a robust space science program? Has the space science program fallen prey to the "big is beautiful" syndrome? What efforts are underway to promote good low-cost science that has shorter lead times and greater potential for graduate student participation?

The current level of funding set forth in the FY 1990 budget is the minimum needed to maintain a vital and productive science program. As noted above, a number of programs originally included in the FY 1990 request were removed due to budgetary constraints, although NASA still maintains a program that will ensure U.S. leadership in Space Science and Applications. The FY 1989 and FY 1990 new starts -- AXAF and CRAF-Cassini -- are major programs with corresponding budgets. However, these missions are designed to last far longer than any previously flown Space Science and Applications missions, some with lifetimes of 15-20 years. The data return from these missions will be unprecedented. Also, we believe that the fraction of the total NASA budget provided to the Office of Space Science and Applications represents a reasonable and appropriate division between investment in infrastructure and investment in use of infrastructure.

In support of the third Program Theme of the Space Science and Applications Strategic Plan ("Frequent flight opportunities for small missions"), we have continued to include in the ongoing program and in the augmentations to the ongoing program small missions that provide new and frequent flight opportunities. This category includes the approved Delta- and Scout-class Explorers, as well as future programs such as Earth Probes and Lifesat.

The Explorer program is a level-of-effort program providing for the study of varied scientific objectives in astrophysics, space physics, and upper atmosphere science. Included in the Delta-class Explorer program are missions such as the Cosmic Background Explorer (COBE), the Extreme Ultraviolet Explorer (EUVE), and the X-Ray Timing Experiment (XTE).

The first missions selected as small-class Explorers include: the Submillimeter Wave Satellite (SWAS) for astronomical studies; the Solar Anomalous Magnetospheric Particle Explorer (SAMPEX) for cosmic ray studies; and the Fast Auroral Snapshot Explorer (FAST) for space physics research. We are developing these missions for launches in 1992 and 1993.

The Lifesat program will use reusable free-flying satellites to study the impact of the space environment on biological systems, and to control unique experimental variables to take advantage of opportunistic conditions, such as solar flares.

The Earth Probes program is envisioned as a scientific complement to the Earth Observing System observations, filling in the gaps that can only be covered by smaller, more specifically targeted free-flyers.

Question 5: What would it cost to complete the development of the Gravity Probe B (GP-B) instrument and to do a space shuttle test in 1993? Was this option assessed by NASA before it terminated the advanced technology work for GP-B?

The current cost to complete the advanced technology program for GP-B, called the Shuttle Test of Relativity Experiment (STORE), is estimated to range between $110 and $130 million for a 1994 launch. If the GP-B program were initiated as an FY 1993 new start, preliminary cost estimates range between $200 and $230 million.

Space Transportation

Question 6: Recently, the Committee was notified by Dr. Fletcher in writing that the space station polar platforms which will house the Earth Observing System will be launched on a Titan IV or a Shuttle-C -- not on the Space Shuttle.

Based on lessons learned, isn't it time to say the polar platforms will be launched on an existing expendable launch vehicle, the Titan IV, and not tie the fate of the program to development of a transportation system that has yet to be approved or developed, the proposed Shuttle-C?

Answer 6: The NASA Polar Orbiting Platform (NPOP) has been baselined on a Titan IV expendable launch vehicle (ELV) launched from Vandenberg Air Force Base. If approved, funding would be required in FY 1991 for a Titan IV in a no-upper-stage configuration to support this mission, as leading-edge payload/launch vehicle integration efforts start approximately 5 years prior to launch. The Office of Space Flight (OSF) would procure the requisite Titan IV launch services from the DOD since large-class launch vehicle services are not commercially available at present. We are also continuing to examine the feasibility of using the Shuttle-C for launch of NPOP from KSC in the event Shuttle-C becomes an approved program. The higher performance of the Shuttle-C would provide greater margin for potential weight growth or additional NPOP experiments.

Question 7: Has NASA initiated another Memorandum of Understanding with the Air Force to acquire Titan IVs for the polar platforms and other missions since the Air Force terminated the prior Titan IV agreement on November 21, 1988?

Answer 7: NASA is currently requesting the DOD to commit to providing Titan IV launch services for the following missions:

MISSION	VEHICLE	LAUNCH DATE	LAUNCH SITE*
COMET RENDEZVOUS ASTEROID FLYBY	TITAN IV/ CENTAUR	AUGUST 1995	ESMC
CASSINI	TITAN IV/ CENTAUR	APRIL 1996	ESMC

In addition, NASA is requesting the DOD to include the NASA polar platforms in their long-term Titan IV program planning.

* ESMC - Eastern Space and Mission Center

The NASA/DOD Memorandum of Understanding on exchange of launch services is effective through 1991. We are currently preparing to initiate negotiations of the extension of the MOU.

Question 8: What additional efforts are being made by your office to secure expendable launch vehicles for space science payloads and as backups to the space shuttle?

Answer 8: The Office of Space Science and Applications (OSSA) keeps the Office of Space Flight apprised via the Civil Needs Database of new missions for which OSF is responsible for ensuring that space transportation is provided. OSF's ELV strategy is predicated upon procuring ELV launch services in four performance classes: small (Scout-class), medium (Delta-class), intermediate (Titan III/Atlas IIA-class), and large (Titan IV class). Requisite ELV launch services will be procured from the private sector, whenever feasible, for civilian government missions that do not require manned intervention or the unique capabilities of the Shuttle.

A request for proposal (RFP) for the small-class services is targeted for release in August 1989, to procure launch services for both identified and future requirements. The RFP for the medium-class services was released in March, with contract award targeted for early 1990. This procurement provides services for the Global Geoscience missions along with options for future requirements. The establishment, on a competitive basis, of a similar commercial launch service ordering agreement for the intermediate-class is on hold pending definition of mission requirements. OSF is currently procuring Titan III commercial launch services for the Mars Observer mission and Atlas IIA commercial services for the Solar-Heliospheric Observatory.

Under current planning, large-class launch vehicle services will be acquired through the DOD, since launch vehicle services in this class are not commercially available at present. Accordingly, Titan IV launch services would be obtained through the DOD to support the CRAF and Cassini missions. This arrangement provides the necessary flexibility to procure additional launch services for missions that may need to unexpectedly transition from the Shuttle.

Data Management

Question 9: Last January, the Wall Street Journal ran a story on page 1 that had the following headline?

> "What Becomes of Data Sent Back From Space? Not a Lot as a Rule?"

The article then indicated that because the necessary software isn't available, we are producing data that can't be handled or analyzed.

Dr. Fisk, what steps are being taken to correct this situation (little being done with gathered data)? Is NASA prepared to initiate a research and technology program to correct this situation that substantially reduces the effectiveness of on-going and planned space science activities?

Answer 9: The fifth theme of the Space Science and Applications Strategic Plan calls for a vigorous research and analysis program that provides base support for a vital and productive research community The FY 1990 budget includes augmentations to and repricings for a number of mission operations and data analysis programs, including those in Astrophysics and Solar System Exploration, for the purpose of furthering and intensifying the analysis of data.

We are also seeking an augmentation to enhance our efforts in developing new strategies and applying new technologies for science data management and archival in FY 1990. These activities will directly enhance our ability to support productive data analysis and interpretation programs. For the longer term, the Office of Space Science and Applications is collaborating with the Office of Space Operations on a comprehensive study to develop an information systems strategic plan for Space Science and Applications.

Questions 10 & 11: How does NASA Space Science and Applications program drive technology advances in different areas? What are some of the better spin-offs from these programs?

Answer 10 & 11: Scientists drive state-of-the-art technology in order to have the ability to perform research at a level that exceeds what is currently available. NASA research programs represent a leading source of new technology, because aerospace programs are, by their very nature, challenging and innovative. The research and experimentation performed in the search for new technology often creates spin-off technology that has commercial application.

In the area of communications, the Office of Space Science and Applications has direct responsibility for basic research in support of technology advancement, leading to new capability. Research involving the Advanced Communications Technology Satellite has produced advances in communications that are currently being used by private industry. In Earth Science and Applications, Earth remote sensing research has been applied to the problem of monitoring and predicting severe storms, improving long-range weather forecasting, and other activities such as monitoring crop health or ocean water pollution.

Certain work in Materials Processing, such as tests of electrophoresis in low gravity, has improved the ground technology of the science as a direct result of efforts to develop and test a space flight capability. In Life Sciences, certain medical diagnostic capabilities needed for the Space Station Freedom have provided the impetus to develop more portable and compact equipment for hospitals. Advanced X-Ray imaging technologies developed for space astronomy missions result in applications in x-ray diagnostic techniques in terrestrial labs.

Earth Observation

Question 12: Dr. Fisk, as you are well-aware, there is considerable interest on this Subcommittee in the global change research program and the proposed Mission to Planet Earth.

What is the level of effort in the proposed FY 1990 budget request for Eos that is to be deployed on the Space Station polar platforms? Do you assume a new start for this program in FY 1991?

Answer 12: In FY 1990 the advanced technology definition studies for the Earth Observing System are included in the ongoing program of the Earth Science and Applications section of the Space Science and Applications budget at $24.2 million. The Eos program is currently being considered as a new start candidate for the FY 1991 budget. As with all Space Science and Applications new starts, a non-advocate review was recently held on Eos. These reviews will determine if requirements, capabilities, technological readiness, and resource constraints of the program warrant a new start in FY 1991.

Question 13: What would be the impact on the Earth Observing System if the Congress were to give the project new start status in the FY 1990 NASA Authorization bill because of this mission's priority status? Has enough advanced definition activity been done on this project to justify a new start?

Answer 13: The Office of Space Science and Applications is not yet technically or programmatically ready to implement the Eos program. Important advanced development remains to be completed in the next year, particularly on certain key instruments, in order to make the program technically ready to proceed. As mentioned above, a non-advocate review was only recently held, and the results of the review have not yet been presented. This major milestone is essential to understanding the readiness of such a program.

Question 14: What would be the impact of a budget cut to the Space Station program on the proposed Earth Observing Program? Is this program severable from the Space Station Program? And should it and the polar platforms be funded under the Office of Space Science and Applications budget?

Answer 14: The impact of such a budget reduction would depend on the scope and depth of the reduction to the Space Station program. The current configuration of both the polar platform and attached payload elements of the Eos program are based on the current configuration of the Station. Since current cost estimates for the Office of Space Science and Applications (OSSA) segment of the Eos program are based on the consideration that the Office of Space Station will budget and develop the polar platform, any budget reduction to this element of the Station program would increase the total cost of the Eos program to OSSA.

Question 15: What efforts are underway within your office to initiate a series of small Earth Probe missions that would assess the level of ozone depletion, measure tropical rainforest, do ocean monitoring research to better understand global climate change?

Answer 15: Currently, a proposed Earth Probes program is under study for a future new start. Key candidate payloads for the program include:

- o Total Ozone Mapping Spectrometer (TOMS)
- o Tropical Rain Measurement Mission (TRMM)
- o Sea-Wide Field Sensor (Sea-Wifs)
- o Geopotential Research Experiment Mission (GREM)
- o Joint Magnetic Mission (JMM)
- o Mesosphere Explorer (ME)

The program would be managed similarly to the Physics and Astronomy Explorer program, in which spacecraft development is phased according to funding availability within a level-of-effort budget.

Question 16: Is the U.S. initiating an ozone mapping survey project with the Soviets? When will those negotiations be completed?

Answer 16: The U.S. is currently continuing feasibility discussions regarding an agreement with the Soviets to fly a Total Ozone Mapping Spectrometer (TOMS) aboard a Soviet Meteor-3 spacecraft, to be launched in 1991. The mission would continue the measurements currently performed by Nimbus-7. The negotiations are being conducted through the U.S./U.S.S.R. Joint Working Group on Earth Science, and, assuming we can reach an agreement on a final implementation plan, should be complete by the Fall of 1989.

Question 17: Is the Earth Probes program a good candidate for international participation with developed and less developed countries?

Answer 17: The Earth Probes program's candidate missions would involve considerable international participation. For the Tropical Rainfall Measurement Mission (TRMM), the Japanese are proposing to provide the rain mapping radar and the launch vehicle, while the U.S. would provide the spacecraft and various instruments. ESA and the U.S. are considering a collaboration on the Geopotential Research Experiment Mission (GREM), and France and the U.S. are considering a collaboration on the Joint Magnetic Mission, although delineation of responsibility for these two missions is not yet defined. As mentioned above, the U.S. and the USSR are considering flying a TOMS aboard a Soviet Meteor-3 spacecraft.

The Earth Probes program is open to the participation of developing countries, and initial interest has been demonstrated by Brazil and other countries with active remote sensing programs.

GAO Reports

Question 18: Last May, the General Accounting Office released a series of reports on the cost, schedule and performance of five major space science missions:

1. Hubble Space Telescope
2. Mars Observer
3. Galileo Mission to Jupiter
4. Ulysses Mission to the polar Plane of the Sun
5. Magellan Mission to Venus

The bottom line was that each had experienced lengthy delays (up to 10 years for Galileo) significant cost overruns (well over $2.5 billion in total) but that performance was for the most part safeguarded.

Dr. Fisk, what lessons have we learned from these programmatic failures? And what additional lessons should we learn?

Although there have been delays and cost increases to the missions of the Hubble Space Telescope, Mars Observer, Galileo, Ulysses, and Magellan, it is misleading to term them "programmatic failures." There are three basic reasons for the increases. First, there are costs associated with manifest changes, particularly the launch delays experienced after the Challenger accident. These costs include "marching army" costs (the cost of retaining a skilled work crew), and costs associated with changes to the missions necessitated by the delays such as changes in trajectory designs, hardware replacements, additional testing, etc.

Second, delays and overruns can occur when new technology is being used and tested for the first time. This is part of the nature of research and development; even small unforeseen difficulties can impact milestones and absorb contingency funding. While all cost estimates anticipate the probability of unforeseen problems, when dealing with radically new or challenging technology such as the HST mirrors or Fine Guidance Sensors, it becomes difficult to precisely assess a priori the potential depth of such problems. Therefore, the need to preserve contingency funds in budget allocations is critical in such programs.

Third, overruns appear to be greater than they may otherwise because of the historical tendency of Congress and NASA to remove reserve funding early in a mission's development life--reserves which are intended to cover problems that may occur as the program matures. In an understandable effort to solve near-term budgetary problems, it becomes tempting to move funds from a project that may not be directly allocated within that project (i.e., reserve funding) and apply them to areas that are in more immediate need. However, when problems arise that require reserve funds which are no longer available, those problems translate into cost increases. In addition, removal of funds early in a program often causes deferral of effort, which ultimately becomes more expensive due to schedule compression when the work is eventually accomplished.

Question 19: If the Congress were to fully fund a Space Science and Applications project at the front end -- give you the check for the total estimated cost of the project and tell NASA to manage the program -- could you do the program on schedule and within cost, or are project managers forced to underestimate the cost of their programs in order to get approval from NASA, OMB, and Congress?

Answer 19: On average over a number of missions, the Office of Space Science and Applications could deliver a project on time and within budget if we were given funds for the total estimated cost of the project. Again, however, the allocation must include protected reserves. One of the purposes of a non-advocate cost review, always held before a project's Phase C/D begins, is to provide an unbiased assessment of the study work conducted prior to the review, as well as an assessment of the project's estimated costs based on historical costing of similar projects and/or an assessment of the technology risk involved. The non-advocate review protects against the possibility of a project manager underestimating the total program costs only to be able to "sell" it to NASA management, OMB, or Congress.

Question 20: What was the last space science program that was brought in at or under the estimated cost and on-schedule? What needs to happen to have another similar experience in the 1990s?

Answer 20: Space science programs such as the International Ultraviolet Explorer, the Solar Maximum Mission, and the Mariner Venus Mercury have completed development within predicted costs and on schedule. More recently, both schedule and cost plans have been significantly impacted by the Challenger accident. Payloads have been waiting for either an Expendable Launch Vehicle or the Shuttle for over three years. Many of these payloads are very delicate and must enclosed in a clean room, monitored, operated, and updated, which is a very expensive process. In terms of recent schedules, however, we have already had some success: the Magellan mission was ready to launch on the first day of a window established over a year ago. The mission was launched one week later, but still well within the scheduled window. It is important to note that during the hiatus caused by the accident, not a single major science mission was cancelled, and all are scheduled to fly during the next five years.

In the future, in order to protect missions from cost increases due to schedule delays, there are three areas on which to concentrate. First, we have realized the need for a mixed fleet. NASA is now committed to maintaining a healthy balance between Shuttle and Expendable Launch Vehicle flights to avoid being dependent on a single launch capability. Second, we have recognized the need to tighten management in the projects. We now have a management philosophy in OSSA in which we pre-negotiate a descoping plan on all science instruments in the event they incur cost increases. Third, we need to continue to invest heavily in advanced technology development so that we can better understand the degree and scope of the risks involved in exploring new areas of technology.

Extended Duration Orbiters

Question 21: NASA was recently instructed by the Congress to develop an extended duration orbiter capability for the space shuttle that would allow the space shuttle to fly missions of 16 days instead of the current missions of 7-10 days. In the future, it is hoped that this capability will be expanded to 28 days.

What is the position of your office towards this initiative (the Extended Duration Orbiter or EDO), and what is its value to the NASA life science and materials processing programs?

Answer 21: The Office of Space Science and Applications strongly supports the EDO program and its objectives. In general, the EDO program will provide extended missions that allow for a broader mix of life science and materials sciences experiments by providing early/late mission emphasis upon life sciences, while preserving long periods mid-mission for materials sciences emphasis.

Life Sciences. The extended mission opportunities that the EDO program will allow present a number of scientific benefits to life sciences research. First, the program provides for more complete assessment of time-dependent phenomena. Most biological processes are dynamic and time-dependent, and 10-day missions only permit the study of acute phases of development, not adaptive or steady state phases.

Second, EDO also offers new windows of opportunity in areas where biological processes require 16 to 28 days to monitor, such as human bone studies, developmental biology, and seed-to-seed plant growth. Finally, the program provides for improved statistical validity, with additional time available in an experiment for an increased number of sessions, an increased number of subjects, and the study of larger effects due to longer exposure to the space environment, such as microgravity and radiation.

Materials Processing. Scientists have estimated that, given access to a 28-day on-orbit capability, 85 percent of all materials sciences objectives could be satisfied. The Extended Duration Orbiter could also provide the following:

- Crystal growth, combustion, fluid, and some critical phenomena experiments clearly benefit from on-orbit durations of 16 days or more;
- Missions beyond 10 days provide efficient use of long module capabilities, and provide for a wider range of multi-user activities;
- Extended missions provide the flexibility to perform iterative and complementary research in a hands-on environment.

Question 22: Am I correct that nearly 50 percent of the proteins that NASA and its researchers would like to study require on-orbit durations of greater than 10 days? And that a mission duration of 28 days would facilitate investigation of all the proposed proteins?

Correct. An on-orbit mission of 10 to 16 days would allow for lower temperature growth, permitting a broader class of proteins to be studied. An on-orbit mission of 16 to 28 days would allow for better control of parameters and therefore more controlled growth, permitting not only a broader class of proteins to be studied, but also permitting those protein crystals to grow to a higher resolution. A mission duration of 28 days would allow the study of a substantial percentage of the individual proteins of interest to the materials processing science community. To make repeated investigations and/or to grow samples of the many different proteins of interest will require a much longer cumulative time in orbit.

Question 23: What medical steps and efforts are required to extend the length of the proposed mission from 10 days to 16 days? What risks does this present to the crew, and what concerns does this present with regard to landing the orbiter?

Answer 23: From the medical perspective, the major operational issues for The extended duration orbiter (EDO) are maintenance of physiological capacity for pilot performance during entry and landing; nominal and emergency vehicle egress; and, monitoring of potential occupational health risks. To address these issues, the EDO Medical Program must extend the knowledge base regarding space flight induced alterations in cardiovascular function, exercise capability, sensorimotor function, environmental health risks, and human factors. With current information, the extended flight times make physiological demands on the crew members that cannot be adequately assessed as to mission impact especially during critical activities such as entry, landing, and egress (including escape). Data collected during Apollo, Skylab, and previous Shuttle missions have shown that numerous physiological changes result from space flight. The STS differs from previous piloted spacecraft since the crew, while seated in an upright position, is subjected to hypergravity stress for 15 to 17 minutes (1.5 +gz) and must perform landing operations that require performance and physical capabilities that were not required before the STS era.

Beginning in FY 1989, an EDO Medical Program is being conductec using near-term missions to:

1. Acquire appropriate data and extend the current data base to assist in the definition and understanding of the operational significance of flight induced alterations in physiology.

2. Develop and verify procedures and countermeasures for optimizing crew performance for nominal and contingency entry, landing, egress during extended missions.

3. Develop STS EDO environmental requirements and capabilities to monitor the air quality, water portability, surface contamination, radiation, personal hygiene, and waste management.

An important part of this program is the gradual buildup approach to attaining full 16-day EDO capability. The plan is to use four 10-day missions with the existing orbiter configuration to gather data; then, initially extend mission duration to 13 days using the EDO orbiter. Finally, if results look good, EDO mission durations will be extended to the full 16-day capability.

Question 24: Would a 16-day mission require an automated landing system on the space shuttle? And does NASA have such a system?

Answer 24: Yes, autoland capability is required for 16-day EDO as a backup mode.

Yes, NASA does have such an autoland system. The plan for 16-day EDO is to use this system at it is currently; manual controlled landing as primary mode with autoland capability available as backup.

Landsat Program

Question 25: Thanks to the direct intervention of the Vice President, Landsat 4 and 5 continue to be operated today. However, it is clear that the commercialization of Landsat has been a terrible failure, and the U.S. must seriously reassess this program and the U.S. goals and objectives in remote sensing (such a review was recently initiated by the National Space Council in the White House).

Dr. Fisk, what role does the Landsat program play in the current global change research program? And should this Nation have an operational earth remote sensing capability?

Answer 25: The Landsat program plays a valuable role in global change research, providing high resolution mapping images of the Earth's surface. This nation continues to need an operational remote sensing capability to serve users with unique requirements for space observations that are not necessarily part of the U.S.

Global Change Research Program. Landsat serves this purpose.

Question 26: Should the Subcommittee transfer the operation and control of the Landsat program back to NASA? If not, why not? Is this one of the options being assessed by the National Space Council review?

Answer 26: The question of which agency should assume the operation and control of Landsat has recently been decided by the National Space Council. The National Oceanic and Atmospheric Administration (NOAA) will remain in operational control of Landsat via a contract with EOSAT.

Question 27: Dr. Fisk, if this Nation cannot afford the Landsat program, can it afford a Mission to Planet Earth or an Earth Observing System?

Answer 27: Landsat and the Mission to Planet Earth concept, or the Earth Observing System (Eos) part of Mission to Planet Earth, have different purposes. Landsat is a commercial applications space observing system. Eos is a long-term earth sciences observation program designed to understand multiple aspects of global change. While Landsat will continue to provide us with important data through the mid-1990s, the scope of Eos will provide us with vast amounts of data needed to understand the interactions of the oceans, atmosphere, and land -- to understand the complete picture of global change.

Earth Observing System

Question 28: A recent press release from the Jet Propulsion Laboratory indicated that JPL will play a major role in the NASA Earth Observing System program and that JPL would be responsible for the development of two polar platforms for this program. The release also indicated that the Goddard Space Flight Center would be responsible for the development of two polar platforms.

Dr. Fisk, am I to assume from this press release that NASA has decided to build multiple platforms with 5-year life expectancy instead of two platforms -- one built by GSFC and one by JPL -- with 15-year life expectancies?

Answer 28: Yes. The current proposed configuration of the Earth Observing System (Eos) platforms calls for a 15-year mission comprised of six platforms with overlapping lifetimes of 5 years each.

Question 29: Was this decision driven by the fact that it is not obvious the servicing of space platforms is cost effective, and it is questionable if the technology to do servicing is available?

Answer 29: A protracted cost review for the Space Station baseline Polar Platform concluded that there was insufficient cost differential for a life-cycle cost-based servicing strategy decision between long duration serviceable platforms and a series of short duration platforms not requiring servicing. Since polar orbit servicing technologies are presently not sufficiently mature, NASA preferred to employ a low-risk option, deciding to pursue a "repair-by-replacement" strategy. Should the technologies mature and become competitive in the future, however, servicing alternatives could be employed on later platforms and/or platform replacements. This option requires that such platforms be designed so they can be serviced, but do not require servicing to accomplish the baseline science objectives. NASA will not accept a platform or payload design which would preclude the potential for future servicing compatibility.

Question 30: Am I also correct that the Office of Space Science and Applications has instructed each of these centers to assume the launch of these polar platforms on a Titan IV, not a space shuttle or shuttle-derived launch vehicle referred to as shuttle-C?

Answer 30: The Eos Polar Platforms are currently configured to be flown on a Titan IV class vehicle; alternate launch vehicles will be reviewed as development progresses.

Question 31: Based on the launch vehicle and servicing decisions, it is the position of your office that the purpose of the Eos missions is to obtain data, not push technologies such as servicing and transportation systems?

Answer 31: The Eos program's primary goal is long-term acquisition of data related to global environmental trends. As with any NASA program of this size and complexity, new technology will be a natural part of the program.

Question 32: Would it also be correct to say that there does need to be a technology push for data management and information systems for the platforms -- computer aided visual data, optical disks and optical storage, etc. -- since they will generate more data than is currently stored on all the magnetic tapes in existence?

Answer 32: Yes. While optical storage technology has been extant for some time, it is still somewhat immature for the needs of the Eos Data and Information System (EosDIS). Because of the vital importance of a large and accessible database to the Eos program, the EosDIS has equal priority in development as the polar platform or attached payload parts of the Eos program.

Nuclear Powered Generators

Question 33: Two of the upcoming NASA space science and missions will use radioisotope thermal generators or nuclear powered generators to fuel the spacecraft -- the Ulysses mission to the polar plane of the Sun and the Galileo Mission to Jupiter. To launch such nuclear powered generators into space requires a Presidential waiver.

What is the status of the waiver requests for the Ulysses and the Galileo missions? What are the principal differences between this current evaluation process and the one that was originally conducted at the time of the Challenger disaster when these two missions were scheduled for launch?

Answer 33: The launch approval process was established in Presidential Directive NSC-25, dated December 14, 1977. The Directive authorizes the Director of the Office of Science and Technology Policy (OSTP) to give approval for such launches unless he or she considers it advisable to forward the decision to the President. This is not a waiver from a prohibition of launch; rather, it is a positive approval. The approval is based upon the results of a Final Safety Analysis Report (FSAR) prepared by the launching program, and a Safety Evaluation Report (SER) prepared by the Interagency Nuclear Safety Review Panel (INSRP).

The status is a follows:

1) For the Galileo mission (launch October 1989):
   - The FSAR has been completed
   - The SER has been completed
   - The launch request will be submitted to OSTP on July 1, 1989.

In anticipation of that request, regular information briefings are being presented to OSTP.

2) For the Ulysses mission (launch October 1990): Much of the detailed safety analysis will benefit from the work done on Galileo as both missions will use the Shuttle/Inertial Upper Stage launch configuration. Although there will be some differences in details of the results, the analytical techniques and verification test data will be similar between the two missions. A detailed schedule for Ulysses is being updated at this time.

Although there are no differences in the evaluation process since the Challenger accident, the current launch configuration is much safer and the safety analytical techniques have been improved. NASA reconfigured both missions to use the solid fueled Inertial Upper Stage (IUS) in place of the Centaur. The IUS, although less energetic, is much more benign than the liquid-fueled Centaur. In addition, during the interval since the 1986 planned launch, there has been extensive additional testing of the RTG. The safety community has extensively analyzed the Challenger and Titan 34 accidents, and has resolved previously conflicting data.

Question 34: Does the U.S. require nuclear power for its proposed space science mission?

Answer 34: The U.S. has a continuing, foreseeable need for nuclear power for its proposed space science missions. Nuclear power is the only available means to power missions to the outer solar system -- an important and exciting science frontier where the U.S. has a unique and commanding technological advantage. For instance, the CRAF-Cassini mission to rendezvous with a comet and to probe Titan's atmosphere will both require RTGs. The CRAF-Cassini Program is the Nation's highest priority space science initiative in the FY 1990 budget. The new U.S. space policy calls for expansion of human presence beyond earth orbit into the solar system. Nuclear power is under active consideration to power lunar bases and equipment on human settlements on Mars.

The report of the Congress of the Committee on Appropriations on the FY 1989 HUD-Independent Agencies bill included the following direction to NASA:

"... the Congress direct the Office of Commercial Programs to conduct a definition/design study of the five year master plan for the establishment of a national repository for federal research and development (technology transfer), which would be located in West Virginia, and to transmit the definition/design study along with five year cost estimates and a proposal for cost sharing, to the Committee on Appropriations of the House of Representatives and the Senate by February 3, 1989."

NASA forward the definition/design study on February 7, 1989 as directed in the conference report accompanying the FY1989 HUD Independent Agencies Appropriations Act (P.L. 100-404). The estimated total costs for development and operations of the National Technology Transfer Center (NTTC) over a five year period were projected to be $37.7M (Table 4.3, P.35, of the Definition/Design Study). The tentative site for the NTTC is Wheeling Jesuit College in Wheeling West Virginia assuming approval of the Definition/Design Study by the Committees on Appropriations of the House of Representatives and the Senate.

NASA's genuine thoughts about the NTTC are as follows:

- NASA supports the NTTC Concept

- NTTC has the potential to enhance the global competitiveness of the United States by facilitating the transfer of federally-sponsored research and development of America's private sector. The NTTC would promote and operate a comprehensive, single point-of-contact technology transfer center for firms seeking federal technology; establish a comprehensive outreach effort with existing federal, state, and local governments and awareness of federal technology opportunities; develop novel methods of accessing federal technology; develop unique databases related to federal technology capabilities and sources of venture and investment capital; and would provide the means to measure the effectiveness of federal technology transfer activities.

- In addition, the NTTC will offer significant benefits to participating federal agencies. Each would be enhanced in meeting their transfer-related responsibilities under the current federal mandates much more effectively as NTTC referrals to these agencies reduce the number of inappropriate inquiries and subsequently produce greater efficiency among federal agency employees charged with transfer activities. Because the NTTC will focus federal technical information services and expertise, it would provide a common point of access for all participating agencies, facilitating more effective transfers, including among the agencies themselves.

I want to apologize to Dr. Lanzerotti and to Dr. Solomon. But now that I have, I would ask you to come forward.

Dr. Lanzerotti is from the Space Studies Board, National Research Council of the National Academy of Sciences. And Dr. Solomon is Chairman of the Space Science Working Group, Association of American Universities. We welcome you both and would welcome your testimony.

I will add further for the record that Dr. Lanzerotti is also from Bell Laboratories, and Dr. Solomon is on the faculty at MIT.

Dr. Lanzerotti, do you want to proceed?

STATEMENT OF DR. LOUIS LANZEROTTI, AT&T BELL LABORATORIES, CHAIRMAN, SPACE STUDIES BOARD, NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES

Dr. LANZEROTTI. Sure. Thank you for inviting me here today on behalf of the Space Studies Board of the National Research Council, National Academy of Sciences.

I will make an introductory statement regarding the board. Since the initiation of the Nation's space program in 1957 and 1958, the National Academy of Sciences through its Space Studies Board has provided advice to the legislative and executive branches of our Federal government as to the scientific and applications thrusts of the civil space program.

In the past year or so, the National Research Council has decided to change some of the advisory responsibilities of several of the boards that provide advice to the Congress and executive branch. In the course of that the Space Science Board has become the Space Studies Board and has taken on the responsibilities to look at a broader range of issues regarding the nation's space program, both in terms of policy, as well as some other issues that we plan to look at in the future, and some areas related to applications, such as the microgravity program and Earth remote sensing.

We have begun to set out a vigorous program to explore these areas and to get in a posture where we can provide the kind of advice you have asked us for and received from us in the past as related to more scientific programs in astronomy and in planetary exploration. That is why we are now called the Space Studies Board, to give the broader perspective that the National Research Council has asked us to take on.

With that as an introduction, I want to make some comments on the NASA budget. My formal testimony has been submitted for the record and I will make some comments and then answer questions.

From the standpoint of the Space Studies Board and the National Research Council, the budget request by NASA represents a national commitment to a strong civil space program and a decision to rank civil space research and technology as a high U.S. priority for many reasons, most of which were articulated very eloquently by Dr. Fisk's previous testimony.

The major new initiative in the budget is the CRAF-Cassini new start. The Space Studies Board supports this new initiative. This new start is based upon the scientific strategies established by the Space Studies Board's various committees, particularly the one related to planetary exploration and two major studies that were carried out by the committee on planetary exploration, one is related to the primitive solar system bodies—asteroids, comets, and meteorites—and was published in 1980; and the other provides advice on scientific strategies for exploration of the outer planets, was published in 1986.

So this initiative does follow through quite well to carry out the scientific strategies as elucidated by American scientists who participated in those studies.

Let me say parenthetically that most of the comments I will make here regarding the Space Studies Board are based upon prior scientific strategies and prior research strategies that the Board has generated over the course of the years in the various committees that the Board supports and which are participated in by a wide spectrum of the U.S. research community.

With regard to the research and analysis funding that is recommended in the NASA budget, and was not discussed very much in Dr. Fisk's testimony, but is supported by the OSSA initiatives, the Space Studies Board strongly supports the increased emphasis that OSSA has placed on resources for research and analysis. These types of resources are fundamental to the space science and applications base program, to our university health and strength.

The JOVE initiative that Dr. Fisk addressed would be considered a part of this research and analysis program which is fundamental for the health and the future, looking toward the future of the U.S. space research program.

Let me make a comment on other aspects of NASA's program which are not necessarily part of the OSSA. The Space Studies Board feels that the issue of a mixed fleets and the aquisition of expendable launch vehicles by NASA is extremely important. Access to space is the single most important ingredient in a vital civil space research program, one that has vision, one that has real potential.

The Space Studies Board believes that the emphasis that NASA has begun over the last couple of years to place on a mixed fleet strategy for the nation's access to space is absolutely the correct direction to be going.

I personally as an individual and as an American citizen still am somewhat worried about our national capacity for access to space, particularly as we get into the era of the construction of the Space Station. I would like to draw to the attention of the subcommittee that I believe that we are still as a nation perhaps somewhat on the margin in terms of capability in the mid-nineties for carrying out all the initiatives that we want. Some attention perhaps needs to be paid to this in due course.

With regard to a couple of other aspects of the NASA OSSA budget, the life sciences, the proposed budget increase for lie sciences research is absolutely necessary if the nation intends to continue to pursue a program of manned space flight.

It is necessary both from the issue of human physiology and medicine, and it is also necessary to explore some of the fundamental questions in biological sciences, a couple of which were enunciated by yourself earlier this morning.

Through its committee on space biology and medicine, the Space Studies Board in a report called "A strategy for space biology and medical science for the 1980's and 1990's" has laid out a scientific strategie; OSSA's budgetary pursuits in this next year will address these recommendations.

Finally, I want to make a comment about the GPB-STORE question which you raised. The Space Studies Board is concerned about the decision not to include funding for the GPB-STORE initiative, the shuttle test of the Gravity Probe B.

We have previously published a report on a strategy for space research in gravitational physics, and we have also—under a previous chairman of the board have issued, letters to NASA Administrators re-emphasizing the scientific strategies which we developed in those fields. On general principle, it is not wise to cancel a program that is vigorous and that is ongoing and that has received as much study as this one has.

In terms of Earth probes, in addition to the major Earth Observing System, the Board's committee on Earth studies has recently issued a report called "A strategy for Earth Explorers," which concerns smaller initiative Explorer satellites to do Earth science.

Funding for these smaller class missions is not included on the OSSA budget. This is understandable given the other constraints on the budget, however we would like to suggest that NASA consider them as initiatives in the next budget year.

This is the end of my summary testimony. Thank you.

[The statement follows:]

(revised 4/10/89)

TESTIMONY

Louis J. Lanzerotti, AT&T Bell Laboratories
Chairman, Space Studies Board
National Research Council

U.S. Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space

April 11, 1989

Thank you for asking me to testify on behalf of the Space Studies Board [1]/ regarding the U.S. space science and applications programs and the FY 1990 NASA Budget Request and other matters pertaining to the civil space program.

FY 1990 BUDGET REQUEST

I will begin with NASA's FY 90 Budget Request. In view of this nation's extremely tight federal budget, we must commend NASA for its vigor in pursuing a strong civil space program. The proposed budget will allow for timely implementation of existing science and applications research and development strategies. We are well aware of the limited resources available and are pleased that investment in civil space research and technology ranks high as a priority.

---

[1]/ The title of the Space Studies Board has been adopted as a replacement for Space Science Board to better reflect our new, broader advisory responsibilities and relationships.

CRAF/Cassini

In particular, we strongly support the decision to proceed with a new start in FY 90 for the CRAF/Cassini program. This is a well studied science program that builds upon a strong legacy of success in the nation's planetary research program (see Strategy for the Exploration of Primitive Solar-System Bodies - Asteroids, Comets, and Meteoroids: 1980-1990, National Academy Press, 1980 and Strategy for the Exploration of the Outer Planets: 1986-1996, National Academy Press, 1986). It is also a time critical program that needs to be begun now in order to meet launch window requirements for the comet and for Saturn. For this reason, as well as for the need to sustain an orderly development of new space research missions as we move into the future, we anticipate that the Committee will view favorably the start of this program this year. In addition to its overall frontier scientific objectives, this particular mission represents a genuine success in establishing international cooperation for the program's implementation. NASA has successfully negotiated a joint research mission with our European partners that can serve as an example for other cooperative ventures in the future. If CRAF/Cassini is not started, or is started and then later cancelled, it could be a potentially serious breach of faith that could jeopardize other partnerships that this country might wish to pursue.

Research and Analysis

The SSB is very supportive of the proposed increased emphasis and resources for Research and Analysis in the NASA budget request. R & A is an integral and critical part of the space science and applications base program as it contributes directly to its health through the work of individual faculty members, investigators, and graduate students at universities and laboratories across the country.

Mixed Fleet/ELV's

The continued support for a mixed fleet for the civil space program is most welcome. Access to space is the single most important ingredient in a vital civil space research program. We applaud the proposed budget increases for Expendable Launch Vehicles. The Board has taken a strong position on the issue of a balanced fleet of launch vehicles, most recently in a position paper released in May, 1986. ("The Nation's Space Program After Challenger: The Need for a Reassessment of The Roles of Manned and Unmanned Systems For Launching Scientific Space Missions," SSB/NRC, 1986).

Life Sciences

The proposed budget increase for life sciences research is absolutely necessary if the nation intends to continue to pursue a program of manned space flight. If the Committee will recall, last year there was a very large (below baseline) reduction imposed on the life science program in the final appropriations bill. Through its Committee on Space Biology and Medicine, the SSB has carried out an extensive study and published a strategy for medical and biological space research, A Strategy for Space Biology and Medical Science for the 1980's and 1990's, (National Academy Press, 1987). This report, which presumes the availability of a space station, recommends a comprehensive and systematic set of investigations designed not only to answer some of the questions necessary to support any national decision to pursue a goal of human space exploration, but also identifies some fundamental biological questions that can only be answered by conducting research in a microgravity environment (see "Space Science Board Assessment of the Scientific Value of a Space Station" and "Space Science in a Space Station Era", SSB/NRC, 9/83). Human exploration by the United States will be among the first of several issues that the Space Studies Board will be intensely studying and providing advice on within the next one to two years. I will discuss this further later in my testimony when I describe the recently reorganized Space Science Board.

We would be remiss in our advisory role if we did not voice our concerns over some of the decisions made by the FY 1990 budget. We do so, with the recognition that our examination of these questions is only from the perspective of the Space Studies Board. As public officials, the leaders of NASA must weigh science mission priorities against the broader budgetary considerations of NASA.

Studies of Gravitation -- (GPB/STORE)

First, we are disappointed and troubled over the decision not to include funding for STORE - the first flight experiment scheduled on a shuttle for the Gravity Probe B research that has been ongoing for a lengthy time. In fact, the technology necessary for this experiment has been in development with NASA sponsorship for nearly twenty-five years. In its report Strategy for Space Research in Gravitational Physics in the 1980's (National Academy Press, 1981), the SSB states that:

> " An experiment that measured the dragging of inertial frames due to a spinning mass would be a landmark in physics -- the first evidence of a magnetic-like effect of gravitation. For example, frame-dragging appears, in principle, to provide the only means for direct measurement of the angular momentum of the sun, a fundamental constraint on models of the solar

> interior..... If a frame-dragging experiment were to reliably disprove general relativity's predictions of frame dragging, it would be a towering achievement."

Again, in 1983 the Board concluded in a letter to J. Beggs, NASA Administrator, December 9, 1983:

> "At its recent meeting, the Space Science Board reviewed the present status of the orbiting gyroscope experiment under development at Stanford University. It is our position at the completion of this review that this experiment continues to merit our endorsement since it addresses the highest priority science objective in gravitational physics."

We would support the continuation of GPB in order to allow for the development of the technology necessary to pursue this high priority scientific objective in fundamental physics.

Earth Probes

Resources for the first Earth Probes spacecraft were not included in this year's request. These small, Explorer class missions were recommended by the SSB's Committee on Earth Sciences (CES) in the Strategy for Earth Explorers in Global Earth Sciences (National Academy Press, 1988) and were also included in NASA's own OSSA Strategic Plan for 1988. The CES report notes the important role that this program would play in making a number of measurements which are critical to global change. Such measurements include those required to maintain the critical time series of atmospheric ozone and ocean color observations in the period prior to deployment of the Earth Observation System, as well as those of global magnetic and gravity fields. We would endorse NASA's stated plans to continue Phase B studies for candidate missions in these areas and we anticipate initiation of the Earth Probes Program in the FY 1991 budget.

Budget Flexibility

These two budgetary items, GPB/STORE and Earth Probes, together with the expected restoration of funding for the ACTS program, give us some cause for uneasiness about what could happen to the proposed OSSA budget as it is discussed and acted upon by the Houses of Congress. We have heard both Dr. Fletcher, Administrator of NASA, and Dr. Fisk, Associate Administrator for the Office of Space Science and Applications, testify that the budget as submitted is "marginal" with virtually no flexibility.

In summary, we endorse and support the science and applications budget that NASA has submitted to Congress for its consideration. While our concerns and reservations about some of the accompanying decisions are real, we understand the fiscal realities of the times and hope that future years will allow for increased flexibility and growth.

SPACE STUDIES BOARD REORGANIZATION

As I noted earlier, the Space Studies Board, formerly the Space Science Board, has recently undergone a phase of self assessment and reexamination. This process was undertaken in order to ascertain how the Board can best serve the nation in the future in its advisory responsibilities for space science and applications. The process resulted in a reorganization of the SSB and a definition of important near-term tasks. As this Senate Committee has had a long-standing relationship with the Board and its discipline Committees, I think it is important for me to briefly summarize the reasons for conducting this reorganization and then outline for you what we will be involved with over the next one to two years.

As you may know, the Space Science Board recently celebrated its thirtieth anniversary. The Board was chartered by the National Academy of Sciences in 1958. Last July, when I assumed the Chairmanship of the Space Science Board, I did so with the agreement from the Academy's managers that this would be an opportune time to look at the SSB of the past and to evaluate whether there might be a need to change some of the existing procedures of the Board in order to better address some of the critical issues facing the civil space program. Over the past fifteen years, the Board has based its advice on long-range research strategies that have been produced by its discipline committees. These strategies represent the Board's reference point from which to advise upon and assess the nation's progress in pursuing and realizing its goals in civil space research. However, with the discipline strategies in place, and with other issues facing the civil research program, we believed that it was time to broaden our focus to better reflect the ever expanding space activities and interests of this nation.

This reexamination process has taken place over the past eight months and has resulted in some significant changes to the activities, scope and purview of the new Space Studies Board. Over two hundred individuals participated vigorously in the activity -- from the scientific community, industry, universities, federal agencies, executive branch offices and congressional committees.

Concurrent with the Board's reassessment process, the Academies made a decision to merge the interests and responsibilities of the Space Applications Board into two other NRC advisory Boards -- the Space Science Board and the Aeronautics and Space Engineering Board. As a result, in addition to assessing how to strengthen the advisory role of the Space Science Board to better address science issues, we also devoted considerable attention to how to incorporate advisory responsibilities for applications - specifically microgravity research and Earth remote sensing - into our purview.

Our reexamination has resulted in a new operating plan for the Board, and a decision to rename it the Space Studies Board to better reflect our national advisory role in the civil space program. Attached to this testimony is this Operating Plan. The following is a summary of its contents.

Broadened Advisory Purview

The Space Studies Board will broaden its advisory purview to include not only NASA's Office of Space Science and Applications, but other relevant NASA offices as well, including the Offices of Space Station, Commercial Programs, Exploration, Space Flight, Aeronautics and Space Technology. In addition, recognizing that important elements of the U.S. civil space program have extended beyond the boundaries of NASA, the SSB will expand its advisory relationships to include other relevant executive agencies concerned with space research and applications. These agencies will include but not be limited to NOAA, NSF and NIH. Lastly, with the growth in foreign space research, the Board must be well informed and sensitive to the role that U.S. space programs will have in foreign policy and in possible new directions for cooperation. We will reestablish a formal liaison with the Department of State for this purpose.

New Initiatives of the Space Studies Board

In the near-term, the SSB will concentrate its efforts in three main areas: following up on its existing research strategies, responding to discipline areas in space applications and undertaking several new initiatives. The SSB will immediately respond to two new areas that have been merged into its enlarged purview by the dissolution of the Space Applications Board: microgravity research and Earth remote sensing. For microgravity research the Board's efforts will be directed toward determining whether the area is of sufficient maturity to warrant the development of a research strategy to assist in its future evolution. The Board will also encourage creative ideas regarding enhancing the interactions of university and industry endeavors in this area. In addition, we will examine current proposals concerning use of the space station for microgravity research and seek to determine how to insure optimized utilization of this facility for these experiments. For space-related studies of the Earth, the Board will work vigorously towards constructing recommendations for coherent national policies to guide the progress of a science and applications program which uses remote sensing and which serves the needs of users.

Additional new initiatives include:

Human Exploration

> "The ultimate decision to undertake further voyages of human exploration and to begin the process of expanding human activities into the solar system must be based on nontechnical factors, and this is appropriately the province of the political process. There is, however, a clear need for substantial scientific and technological research to provide a foundation on which such a decision can intelligently be made." (Toward a New Era in Space--Realigning Policies to New Realities, Recommendations for President-Elect George Bush, NAS/NAE, 1989)

The new Space Studies Board has a major responsibility to provide the advice on the scientific and technological considerations and research that must accompany any decision to undertake human exploration. In so doing the Board will consider precursor studies, opportunities for scientific research, necessary technological development, alternative exploration strategies and costs and tradeoffs.

Priorities in Space Research

The SSB will document the role of space research in the overall research efforts of the United States; it will participate in the national debate over the priority of space research and technology in a national context; and it will investigate the development of procedures for setting priorities among its various recommendations on science programs and supporting activities. It will also validate the present strategies of the SSB in consultation with its committees and provide prioritization advice.

Technological Development for Science and Applications

The Board will work to identify the critical technologies necessary to accomplish the science and applications goals in its strategies and long-range plans, will review NASA programs that are developing the technologies to insure that science and applications requirements and their optimization are met; and will encourage the NASA/University/Industry partnership in identifying and developing technology. In cooperation with the NRC's Aeronautics and Space Engineering Board, we will examine the feasibility and terms of reference of advising on cost and trade-off issues that directly affect research productivity.

International Issues and Guidance

The SSB will study the issues arising in the growth of international capabilities in space endeavors and provide advice to encourage appropriate cooperation to the benefit of space research and applications.

Costs and Tradeoffs

The Board will consider the major issues concerning the implementation of programs that directly affect scientific productivity. Some of these issues may include: orbit and transportation system selection, data retrieval and distribution systems, management approaches, operations concepts, reliability requirements, overall mission planning, cost development models, and life cycle costs. The intent is to try to develop a rationale for considering trade-offs between viable programmatic options to maximize productivity from the point of view of the user.

This concludes my summary of the structure and planned advisory activities of the new Space Studies Board. Our intent is to continue to provide, under the auspices of the National Academies/National Research Council, the best, most relevant and timely, and independent advice possible and to the widest audience of citizens and leaders possible. We will continue to call upon the leading members of the American scientific and engineering communities to devote their creativity to the advisory tasks. We invite you to follow our progress and hope that you will call on us in the future if we can assist you in any way. Thank you.

OPERATING PLAN FOR THE SPACE STUDIES BOARD

With disciplinary strategies in most fields now in place, the Space Science Board will focus on broader, interdisciplinary issues during the next few years. This new emphasis will respond to critical questions arising on the national and international agenda for civil space research. While addressing these new issues, the Board will continue to monitor the progress of its existing research strategies. Further, it will incorporate the Board's role in two new technical areas growing out of the merger with the Space Applications Board. In recognition of its expanded purviews, the Board will change its name to the Space Studies Board.

BACKGROUND

For the past 15 years, the Space Science Board and its committees have utilized the long-range research strategy concept as the basis for providing advice to NASA's Office of Space Science and Applications. Taken collectively, the current strategies represent: (1) the Board's advisory policy on the national civil space program; (2) the Board's reference standard when periodically assessing progress in implementing the decade-long strategies, thereby measuring the health and vitality of the U.S. research effort. The influence of the strategies is pervasive; in virtually all other statements or reports, the conclusion and recommendations are based on the Board's vision of the U.S. space research enterprise, as portrayed in the strategies.

The Office of Space Science and Applications has established a strategic plan to implement these research strategies to the mid-1990's. Due to long delays in previous development schedules, including the hiatus in launch opportunities, current advisory strategies are sufficient to guide current mission plans. Therefore, the Board will defer the development of new strategies for approximately the next five years. The Board reserves the option, however, to initiate strategy development in microgravity sciences and in Earth remote-sensing applied sciences, should a current assessment indicate it is timely and appropriate.

In addition, this plan for the Board's operations must remain flexible. The Board must be able to change the details of this plan as necessary in order to adjust to changing circumstances.

SCOPE AND PURVIEW

In the past, the Space Science Board's and the Space Applications Board's services have been directed almost exclusively to the Office of Space Science and Applications (OSSA). The broad nature of the new issues being taken on will require the Space Studies Board to broaden its contacts and establish regular lines of communication with NASA codes and divisions outside the OSSA -- those that are directly involved in the science and applications programs on which the Board will be providing advice at any given time.

It is now clear that the U.S. civil space program has extended well beyond the boundaries of NASA. The same logic that supports expansion of the SSB's advisory relationships within NASA applies to other executive agencies involved in space research and applications. The addition of applied research to the Board's purview makes this argument particularly compelling. Special emphasis will be devoted to possible advisory relationships with NOAA, NIH, and NSF. Moreover, if the Board is called upon to provide prioritized advice it must take into account the relevant space-related activities in the other federal program and policy agencies.

Lastly, with the growth of foreign space research, the Board must become increasingly informed and sensitive to the role that U.S. programs have in foreign policy and new directions for cooperation. The Board should reestablish formal liaison relationships with the Department of State for this purpose. It should also extend its area of interest to include the plans and programs of other nations with major programs in space.

ISSUES AND TASKS FOR THE BOARD

During the next few years the Board will concentrate its efforts in three main areas: following up on existing strategies, responding to discipline areas in space applications, and undertaking several new initiatives.

1. Immediate Response to New Disciplinary Areas in Space Applications

The SSB will develop activities to investigate the status of and to propose an advisory role and mechanism in the following two areas:

- Microgravity research
- Earth observations from space

The intent for microgravity research is to determine if the area is mature enough and amenable to the development of a research strategy to assist in its future evolution. If this proves not to be the case, the Board will continue to monitor the development of the field until such time as a strategy is appropriate.

For Earth observations from space, the intent is to try to construct a coherent point of view for guiding the progress of a science and applications program utilizing remote sensing and serving the needs of users.

2. Follow Up On Existing Strategies

The Board and its committees will meet regularly with NASA representatives to monitor the progress of research according to existing research strategies. A continuing concern is the progress that NASA makes in improving access to space.

While the development of subsequent strategies is deferred, the Board will maintain the science objectives and recommendations represented in the current strategies as its advisory base in considering and addressing major new issues that impact U.S. space research, changes in scope of the Board's advisory purview, and the annual assessments of the progress and problems of NASA in implementing the current science mission plan.

3. New initiatives

The Space Studies Board will address over the longer term the following new interdisciplinary tasks, in priority order:

- **Human Exploration**

"The ultimate decision to undertake further voyages of human exploration and to begin the process of expanding human activities into the solar system must be based on nontechnical factors, and this is appropriately the province of the political process. There is, however, a clear need for substantial scientific and technological research to provide a foundation on which such a decision can be intelligently made." (Stever Committee, NAS/NAE, 1989) The Board has a major responsibility to provide the advice on this scientific and technological research.

- **Priorities in Space Research**

The Space Studies Board will document the essential role of space research in the overall research efforts of the United States; it will participate in the national debate over the priority of space research and technology in a national context; and it will investigate the development of procedures for setting priorities among its various recommendations on science programs and supporting activities.

- **Technological Development for Science and Applications**

The Space Studies Board will work to identify the critical technologies necessary to accomplish the science and applications goals in its strategies and long-range plans, will review NASA programs that are developing the technologies to ensure that science and applications requirements and their optimization are met; and will encourage the NASA/University/Industry partnership in identifying and developing technology.

- **International Issues and Guidance**

The SSB will study the issues arising in the growth of international capabilities in space and provide advice to encourage appropriate co-operation to the benefit of space research and applications.

- **Costs and Tradeoffs**

The Board will consider the major issues concerning the implementation of programs that directly affect scientific productivity. Some of these issues may include: orbit and transportation system selection, data retrieval and distribution systems, management approaches, operations concepts, reliability requirements, overall mission planning, cost development models, and life cycle costs. The intent is to try to develop a rationale for considering trade-offs between viable programmatic options to maximize productivity from the point of view of the user. The SSB should work closely with the ASEB to develop this activity.

THE REVISED ORGANIZATION OF THE SPACE STUDIES BOARD

The revised organization will consist of a Board, several standing committees for long-term activities, and several task groups which address shorter-term issues. Some of these groups will be formed within the Board and will include members drawn from those disciplines in space sciences and applications that fall within the purview of its advisory responsibilities.

Since several of the proposed tasks for the reorganized SSB are new, it must be understood that the terms of reference and suggested structures for pursuing them will require further definition and may change from the concepts described in this document. In some cases, these new tasks will first require a development phase, during which the details of the activity will be established.

A. Proposed Standing Committees

1. Discipline Committees

Standing committees, representing several disciplines within the space sciences and applications, would be charged with providing advice to the Steering Committee on Human Exploration and to other Board committees and task groups, with answering Board requests for information, and with reviewing discipline strategies when required. These Committees will receive strong direction from the Board relative to their agendas, size, and frequency of meetings. The proposed committees are in the areas of:

- Astronomy and Astrophysics
- Solar and Space Research
- Earth Observations
- Planetary Research
- Space Biology and Medicine
- Microgravity Research

2. Steering Committee on Human Exploration

This committee would consist of Board members and would receive input from the discipline committees. Joint membership or liaison members with the discipline committees could aid the assembling of information. The Board would provide advice on the scientific and technological research that must accompany any decision to undertake human exploration. Such advice would consider precursor studies, opportunities for scientific research, necessary technological development, alternative exploration strategies, costs and tradeoffs.

3. Committee on Technological Developments

This committee will provide advice on the requirements for technological developments necessary to undertake the Space Studies Board's research strategies and long-range plans. The size, composition, and charter of this committee will be determined by joint consultations between the ASEB and the SSB.

B. Proposed Task Groups

1. Priorities in Space Research

This Board-led task group will assess the role of the space sciences and applications in the nation's scientific agenda. It will also validate the present strategies of the Space Studies Board in consultation with its committees and provide prioritization advice.

2. Costs and Tradeoffs

This task group, appointed jointly by the Board and the ASEB, will examine the feasibility and terms of reference of advising on cost and trade-off issues that directly affect research productivity.

C. Other Tasks

Issues concerning data management and information systems must be addressed within the broader scope and purview identified for the Board. The issues arising from the increasing flow of data from space missions and the related information systems required to process and distribute these data have permeated all space research disciplines. The Board will consider these issues in collaboration with other NRC units, including the ASEB.

Issues involving international cooperation will be addressed by the Board as a whole on a continuing basis. Research matters associated with the subject area of exobiology will be addressed by an ad-hoc subcommittee of the Board. For questions on issues such as Planetary Protection, a special working group will be formed, as appropriate, of members of the cognizant communities.

WORK PLAN FOR THE FIRST YEAR

The SSB will establish new discipline committees in earth studies and microgravity. The proposed discipline committees will provide follow-up on existing strategies and ongoing activities.

In its first year, the Board will address the following new tasks:

- Human exploration
- Issues related to prioritization
- Research requirements for advanced technology development

ADVISORY RELATIONSHIPS

The changes in the Board's new advisory form, subject matter, and scope and purview require certain readjustments in its advisory relationships:

- Within federal program agencies. The advisory relationship with NASA will be expanded. The Board will advise other codes that support science and applications or that are responsible for major technological enterprises. No apparent barriers have been identified that would inhibit the expansion of the Board's purview, not only into related programmatic areas but also to policy and decision-making levels. The Board will act quickly, as an initial step, to establish formal liaison relationships with important relevant agencies, in particular, NOAA, NSF, and NIH. The Board will also develop close working relationships with OSTP and the new Space Council. Further, the Board will work toward developing a relationship with the relevant space elements of DoD.

- Within NASA internal advisory bodies. The recent reorganization and redefinition of committees under the NASA Advisory Council (NAC) will affect relationships with the Board's advisory posture and scope. The SSB will develop close coordination with the NAC subcommittees (particularly the Space Science and Applications Advisory Committee and the Aerospace Medical Advisory Committee).

- Within the NRC. The SSB will establish close working relationships with the ASEB where warranted. The SSB or its discipline committees will establish the appropriate liaison relationships with other NRC committees and boards as required.

Senator **Rockefeller**. Dr. Lanzerotti, thank you.
Dr. Solomon.

STATEMENT OF DR. SEAN SOLOMON, PROFESSOR OF GEOPHYSICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, AND CHAIRMAN, SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES

Dr. **Solomon**. Thank you, Mr. Chairman. I am here on behalf of the Space Science Working Group of the Association of American Universities and the National Association of State Universities and Land Grant Colleges, which together represent the majority of major research universities in this nation.

I would like to echo many of the remarks that committee members and witnesses have already made about the enthusiasm for upcoming missions in the space sciences. I am myself an investigator on the Magellan mission, looking forward to the launch of that mission to Venus in two and a half weeks.

As I was preparing my remarks for today, I could not help thinking back to the first meeting I attended to plan for that mission. That meeting was in 1977, 12 years ago, six Congresses ago. I was a very young and junior faculty member, full of optimism and enthusiasm for the space program.

The space program was in the midst of an era of great accomplishment in planetary exploration. We had just flown by Mercury, and we'd had two flyby's of Jupiter. The launch of the Voyagers was imminent. The Galileo program had received a new start. We were about to fly by Saturn for the first time. A new mission seemed to offer an opportunity to enter a field that promised a continuous stream of new data and excitement.

And as you all know, that situation changed dramatically over the intervening 12 years, as this Nation's space program fell into a long period of deep freeze. I like to think we are closing that cycle and returning to a period of discovery and excitement again.

Today I wish to share a few thoughts with you on behalf of the Space Science Working Group about the space program in general and then offer our comments on the fiscal year 1990 budget for OSSA.

The witnesses before me and members of the committee have enumerated all of the reasons why the United States should endeavor to carry out a vigorous program in space. A space program, including space science, stimulates us intellectually. It drives our technological capabilities. It captures our collective imagination and stirs our emotions as a people.

[The statement follows:]

STATEMENT OF SEAN C. SOLOMON, ON BEHALF OF THE SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES, AND THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

Mr. Chairman, Members of the Subcommittee, thank you for this opportunity to testify on the subject of NASA's Space and Earth sciences program. My name is Sean C. Solomon, and I am a Professor of Geophysics in the Department of Earth, Atmospheric, and Planetary Sciences at Massachusetts Institute of Technology. I am speaking here today as a member of the Steering Committee of the Space Science Working Group (SSWG) of the Association of American Universities. I am testifying on behalf of the Association of American Universities and the National Association of State Universities and Land-Grant Colleges, whose members represent most of the major research universities in the United States.

After the prolonged hiatus in the U.S. space program, the next 12 months will initiate a dazzling return to exciting accomplishments for the space sciences. Later this month, NASA will launch Magellan, the first U.S. planetary mission in more than a decade, to map the surface of Venus. In close succession will be the launches of the Cosmic Background Explorer, the Galileo mission to Jupiter and its satellites, and the first two of the Great Observatory series, the Hubble Space Telescope and the Gamma Ray Observatory. In August, Voyager 2, launched 12 years ago and continuing to yield important data, will send humankind the first spacecraft data from Neptune, presently the most distant planet from the sun.

Poised as we are on the threshold of an new chapter of discovery for the U.S. space sciences, it is timely to restate the rationale for a vigorous national civilian space program. In the context of this rationale, the SSWG would like to offer its view of the FY 1990 NASA budget before you.

A VIGOROUS SPACE PROGRAM AND NATIONAL PRIORITIES

As an element of national policy, a strong and active space program provides a highly visible demonstration of this nation's scientific and technological prowess. At an intellectual level, space science epitomizes our innate inquisitiveness about our environment and our place in the cosmos. At a technological level, space presents profound challenges that drive industrial creativity. At an emotional level, space offers the unique opportunity for all of us to experience the thrill of exploration of an expanding frontier. The U.S. space program must achieve a balance among these perspectives, which calls, in turn, for a balance between science and applications, between manned and unmanned activities in space, and between infrastructure and new initiatives.

As the scientific exploration of space moves outward to distant planets and galaxies, the growing public concern over the fate of our own planet underscores the crucial role of space science for understanding the workings of Earth. With issues such as the deterioration of the ozone layer and secular global warming drawing accelerated worldwide attention, the space-science community will bear an increasing responsibility to provide the technical context for political decisions at national and international levels. Our national space program must continue to seek the new data necessary to provide this context.

Mr. Chairman, I believe that NASA's space science program should be viewed in the context of a topic being widely discussed throughout the science community and of particular concern to Congress and this Committee: the need to have an accepted process for setting scientific priorities. This discussion is the result of the fact that the cost of conducting leading-edge science in every discipline exceeds available resources. This truism has forced policy-makers to choose between funding fewer programs at adequate funding levels or pulling along a greater number of programs "by their boot-straps." This Committee has responded to this challenge by consistently authorizing funding for NASA's space science program at responsive levels, while simultaneously insisting that NASA provide the Committee with a straightforward, cross-cutting set of priorities for future scientific missions. It is in this context that I would like to commend the work that NASA has done in the form of the Office of Space Science and Applications (OSSA) Strategic Plan. Under the leadership of NASA Associate Administrator for Science and Applications, Lennard Fisk, NASA's science program has made substantial progress toward establishing far-sighted and balanced priorities for our space science program. I can tell you that, as a practicing scientist, the stability and predictability that this provides the entire community is most welcome.

A robust space science program also can help address another pressing national priority – the need to reverse the declining interest and skill in science and mathematics in elementary school children. It is essential to strengthen those national programs that capture the scientific and technical imagination of our population. Our space program has been and can continue to serve as a catalyst in this area. One need look only at the continued large crowds at the National Air and Space Museum, public fascination with discoveries of a new supernova or the rings of Uranus, and the consistently high turnouts to view the space shuttle launches and landings to recognize the power of space exploration to drive the curiosity of child and adult alike.

Harnessing that curiosity to attract the next generation of scientists and engineers should be an important objective of our national space program. This is particularly true from a university perspective. After all, universities have traditionally provided the backbone for space science research in this country and are a major source of new scientific theories and of new ideas for spacecraft instruments. At least equally importantly, universities are the principal source of new scientific talent, through the training of graduate students and postdoctoral researchers. The declining opportunities in the space sciences over the past several years have posed serious obstacles to attracting and retaining the best young scientific minds. As a result, the generation of young space scientists who will conceive and carry out the next set of scientific missions is dangerously underpopulated. For example, during the 1970's in my department at MIT, we graduated 22 Ph.D.'s in planetary science. In contrast, during the first 8 years of the 1980's we graduated less than half that number. Recently, however, we have seen a widespread renewal in enthusiasm for work in planetary science on the part of prospective and new graduate students, enthusiasm fueled by anticipation of the opportunity to work next year with data from Magellan and the Hubble Space Telescope. Clearly a vigorous and broadly conceived U.S. space program is the prescription for repopulating the ranks of young space scientists.

THE PROPOSED FY 1990 NASA BUDGET

I would now like to focus on the proposed FY 1990 NASA budget in the context of how responsive it is to the various objectives of the space program. The SSWG commends NASA and President Bush for submitting a FY 1990 budget which advances several areas of the space program of importance to the university space science community. We are heartened by the continued program development in the recent major new starts for AXAF and Global Geospace Science. This orderly implementation of the OSSA Strategic Plan gives our best assurance for recapturing U.S. leadership in space science. Of special importance to the university space science community are the new initiatives in the balloon and suborbital rocket programs and the augmentation of the Explorer line to fund the new Small Explorer missions. These relatively modest programs are of an ideal size for strong university participation and have time scales commensurate with the training of graduate students and the career development of young faculty. We particularly applaud the procurement of expendable launch vehicles which will provide the U.S. space science program with frequent and assured access to space.

The SSWG strongly endorses the proposed new start for the CRAF/Cassini mission and the essential increases in the research and analysis (R&A) components of the OSSA budget. The CRAF mission will provide the first long-term study of a comet, including *in situ* analysis of material thought to be little altered from the earliest beginnings of the solar system. The Cassini mission, to be carried out in cooperation with the European Space Agency, will give us in-depth observations of the atmosphere, magnetosphere, rings, and moons of Saturn, as well as chemical analysis of the thick atmosphere of its intriguing, haze-shrouded moon, Titan. Both missions, coupled with other "new starts" on line in the strategic plan, will serve to maintain a vigorous program of U.S. solar system exploration well into the next century.

The increases in the R&A components of the OSSA budget reverse a long erosion of support for basic research, analysis and management of data from past missions, and advanced technology development - all essential ingredients of the efficient planning for the next generation of activities in space. The increases are particularly welcome in the space life sciences, which bore a disproportionate and debilitating share of the budget cuts in FY 1989. Programs which had been originally slated for this year, including development of a centrifuge facility, and planning for initiatives in space biology and extended duration crew operations, can finally begin in FY 1990. Indeed, the R&A programs are the lifeblood of university space science in its role of attracting and training the next generation of engineers and scientists. We also commend NASA for continuing its support of the NASA Graduate Researchers Program, which funds 245 new and continuing awards to outstanding students pursuing career interests in space-related fields of study.

The overall FY 1990 NASA request is $13.3 billion, a 22% increase over FY 1989, while OSSA's portion is slated for a 9% increase, from $1,830 million to $1,995 million. Given the tight constraints on the federal budget, we view this budget submission as a serious commitment from the Administration that leadership in space is an important policy priority. A close analysis of the OSSA portion of the budget, however, shows that it is extremely tight, with little or no flexibility for unanticipated events or opportunities. The missions operations and data analysis budgets, for instance, show large increases in FY 1990, but these increases will principally support the missions to be launched in the next 12 months. Funds to support currently operational spacecraft are dwindling despite opportunities for measurement of new phenomena, particularly in the space physics field. Moreover, the SSWG is distressed about several aspects of the budget as submitted.

Mr. Chairman, as the spokesperson today for the primary university-based policy group concerned with NASA, I would like to raise an issue of central concern regarding the way universities work with NASA. As you know, universities often make significant investments in people and facilities to support NASA goals. While there is never a guarantee that the government will continue to fund every program, there is an understanding that meritorious programs which are endorsed by peer review will usually receive continued support.

It is in this light that I wish to bring to your attention the proposed cancellation of the Shuttle Test of Relativity Experiment (STORE) program. This program, often referred to as "Gravity Probe-B," is designed to test Einstein's theory of general relativity. This project, which encompasses large advances in science and technology, was contracted to Stanford University in FY 1985 and is a two-phase flight program leading to a 1995 mission. This approach has received the enthusiastic support from the National Academy of Sciences, NASA, Congress and the OMB. Since contracting with NASA in

1985, Stanford University has dedicated nearly half an acre of laboratory and office space to Gravity Probe-B and has invested over $650,000 in this program. This program has heretofore been a model for a NASA-university partnership directed toward achieving a technologically challenging and scientifically fundamental goal. However, despite these commitments and a series of superior external evaluations, NASA, for macroceconomic reasons, has proposed "zeroing" this program in the FY 1990 budget. If this program is canceled, it may have long-term consequences for future NASA-university cooperative ventures. The SSWG requests that Congress find a mechanism for restoring STORE by adding $25M to the OSSA request for this program.

Two other initiatives, modest in cost but large in importance, were also not included in the budget request: the Earth Probes spacecraft series (the first of which would monitor the temporal and spatial variations in the Earth's ozone layer) and a program to place U.S. experiments on international missions. The delay or loss of the ozone mapper is serious given mounting concern over the ozone depletion problem, and candidates for later spacecraft in the series to monitor ocean color, to map the Earth's geopotential fields, and the measure global rainfall represent key elements of a coordinated Mission to Planet Earth. The loss of foreign mission support means that unique opportunities for low-cost U.S. participation on foreign missions, including a powerful Soviet X-ray telescope, may be lost. In addition, international collaboration saves wasteful duplication of effort.

Finally, because of the tightness in the budget, the addition or restitution of major programs, such as the Advanced Communications Technology Satellite, without the corresponding addition of resources would severely damage the carefully crafted OSSA strategic plan and the orderly accomplishment of ongoing programs. The impact on other elements of the OSSA budget could be very significant.

Mr. Chairman,we should not lose sight of the need for balancing the space science program with the rest of NASA's program. In order to avoid repeating mistakes learned from the shuttle program, Congress has decided that one way to maintain a balance between hardware development and science is to mandate that at least 20% of NASA's R&D and space flight budgets be allocated to space science programs. This sentiment was reflected in the FY 1988 Appropriations bill for NASA, which stated, "... the conferees note that the Agency is committed to maintaining funding for science and applications at not less than 20% of total NASA resources. Although to date NASA has honored this commitment, the conferees are concerned that further budget constraints could negatively impact unmanned activities." (H.J. Res. 395: Conference Report 100-408, page 856.) This Committee has actively supported this approach and NASA has concurred. This policy helps ensure that space science, the basis of America's future in space, will not be asked to assume the burden of cost over-runs or administrative planning errors in other parts of the space program.

The SSWG is concerned that the proposed budget for Space Science and Applications may be below the minimal level of support necessary to make the most effective scientific use of the nation's scarce space missions. By submitting a budget for OSSA which is less than the 20% level, NASA, in effect, undermines the policy established by the Congress to guarantee the availability of funds sufficient to maintain the minimally necessary level of research support, including payload flight opportunities.

We continue to believe in the soundness of previous NASA and Congressional reasoning that set the minimum budgetary investment in space science at the 20 percent level. While the SSWG recognizes the strong fiscal constraints imposed by the Brobdingnagian federal deficit, we nonetheless urge Congress to restore the appropriate balance to our nation's civil space program. Specifically, a return of OSSA to the 20 percent level would permit the restoration of STORE and the initiation of the Earth Probes series, would enhance international scientific cooperation in space exploration, and would provide needed increases to mission operations and data analysis budgets.

SUMMARY

With the proposed FY 1990 budget, NASA will continue its implementation of a long-term plan that will return this nation's program in space science to one of vision and vitality. The plan remains responsive to the recommendations of NASA and NAS scientific advisory committees. The FY 1990 budget continues to aim for balance among support for ongoing programs, diversification of the launch vehicle fleet for space science missions, increased support for research and analysis and technology development, and new initiatives in life sciences and solar system exploration. With modest and carefully targeted additions to the space science program, this budget will constitute a major step toward assuring a fully balanced program of space science and applications and will accelerate American efforts to regain leadership in space. At the very least, we request approval of the Space Science and Applications budget as submitted by President Bush. Hard choices have already been made and squeezes have been effected in order to provide for new missions. A major cut (or a restoration of a program without funds) would result in a drastic setback to the space science program.

Thank you again for the opportunity to present this testimony. I would be pleased to answer any questions.

Senator **Rockefeller**. Dr. Solomon, can I interrupt you and ask just what it is that you will be, what kinds of studies you will be doing with respect to the Magellan?

Dr. **Solomon**. Certainly. Would you like me to comment on that now?

Senator **Rockefeller**. Yes.

Dr. **Solomon**. Okay. The Magellan mission is a radar mapping and altimetric mission to Venus. In many respects Venus is the closest planet to the Earth. It is the closest in distance, and it is the closest in radius and mass and bulk density. We think it is made out of the same kinds of materials as the Earth.

Venus has nonetheless had a very different history, a history dominated by a run-away greenhouse in the atmosphere and consequently a very high surface temperature. On the Earth many of the characteristics of what we call plate tectonics—the dynamical processes that give rise to all of our earthquakes, most of our volcanic activity, the motions of the continents, the formation of huge mountain belts—are products of the internal evolution of our planet. Venus ought to have had a comparable internal evolution, and yet preliminary results from Soviet spacecraft and from Earth-based radars suggest that Venus has had a very different history.

So Venus offers a rare opportunity to contrast a planet that shares many characteristics with the Earth and yet has had a very different evolution. It provides perhaps our only window in the solar system on why an Earth-like planet might end up with a very different evolution and very different characteristics.

We want to study the geological evolution of Venus in detail, both to learn as much as we can about an important planet in the inner solar system and to contrast with our understanding of how the Earth works.

Senator **Rockefeller**. Thank you.

Dr. **Solomon**. I wanted to add as an introductory remark something well known to all of you, that universities play an essential role in space science. Universities are a source of new ideas, new theories, and new technologies. And, of course, the universities are the principal source of new blood, the new graduate students, new postdoctoral researchers, and young scientists needed to conceive, to plan and to carry out the next generation of missions in all of the space sciences.

At my own institution, at MIT, there is an interesting contrast again between the 1970's and this decade in terms of the productivity of our department at producing Ph.D.-level scientists. One statistic may be illustrative: In the 1970's our department graduated 22 Ph.D.'s in planetary science. The 1980's is not complete—we have only had eight years—but so far we have produced less than half of the number of Ph.D.'s that graduated in the seventies. I think this contrast is in large measure a response of the student body to the perception of a lack of opportunities in the space sciences over the last ten years.

But that perception is changing. Even now, in recruitment of new graduate students, we see a growing excitement about participating in space missions, opportunities such as Magellan and the Hubble Space Telescope. Again, the cycle may be coming to a close.

Mr. Chairman, I would like to divide my remarks on the OSSA 1990 budget into two parts, the good news and the bad news. We are very pleased with many aspects of the OSSA budget, not the least of which is the OSSA strategic plan. The university space science community supports the clearly enunciated goals that are laid out in that plan as well as the carefully conceived balance among disciplines and among approaches taken to achieve those goals.

We are pleased as well to see the continued development of ongoing programs, including important new starts of recent years, such as GGS and AXAF. The university community is especially supportive of some of the smaller science efforts at NASA: the small Explorer line; the sub-orbital and balloon programs which are being augmented in the 1990 budget; and the effort to continue to diversify NASA's launch vehicle fleet.

We very much support the new start for CRAF-Cassini. In the space sciences this is the number one priority new start. It has long been on the planning boards in the planetary sciences. The CRAF mission offers the U.S. the first opportunity to rendezvous with a comet and to sample directly material that is thought to be little altered since the origin of the solar system.

The Cassini mission allows us to study in depth the diversity of phenomena in a very complex planetary system with an ordered array of satellites and rings and a magnetosphere. The Saturn system includes the very intriguing moon, Titan, which may offer the chance to study pre-biotic organic chemistry by means of an atmospheric probe.

The university space science community is very pleased with the increases in the 1990 budget for the research and analysis parts of the OSSA program. We have come before this and other committees in prior years with the message that the research and analysis budgets in NASA have been undergoing a dangerous erosion, a continued decline that has sapped our ability to attract students at universities, to bring new people into the field, to capitalize on the information that has been obtained from space, and to build toward the next set of missions in all of the space sciences. This budget is a very welcome reversal of that trend.

These positive aspects of the FY 1990 OSSA budget notwithstanding, we wish to voice several concerns. In general, we are concerned with the tightness of the budget, the lack of any opportunity for flexibility to respond to new phenomena and the very stringent limits on funds even to maintain and recover data from currently operational spacecraft.

I would like to highlight in particular our distress with the elimination of a major ongoing program, the Shuttle Test of Relativity Experiment [STORE], perhaps the most serious outcome of the tightness of this OSSA budget.

STORE, as many people have mentioned already here this morning, is a premier scientific experiment. It has been reviewed countless times by the National Academy of Sciences, by internal NASA committees, and by external advisory bodies. It represents excellent science, a unique test of a fundamental aspect of our understanding of a basic physical law, and it is extremely challenging technologically.

From the standpoint of the SSWG, STORE has heretofore been a model for university-NASA relations, Mr. Chairman, as you have pointed out. Stanford University and NASA have joined in partnership to carry out this experiment, and both sides have committed major resources. Stanford has committed personnel and building space, as well as substantial funding. Just when this program is poised on the threshold of a key test of the ability of the experiment to achieve its objectives, NASA is now proposing cancellation. We urge Congress to find a means to restore STORE to the OSSA budget.

Several others have mentioned the important scientific programs that could not be initiated next year for financial reasons: the Earth probes series and the program to place U.S. instruments on international missions.

In the Earth sciences community, although there is considerable support for EOS, there is also widespread recognition that we need to fly small missions as well as large ones. The Earth probes series will fill that niche very nicely and will allow us to make a number of measurements that will help us understand the fragility of our planet and the scientific phenomena that we need to characterize in order to respond to that fragility.

In summary, Mr. Chairman, the Space Science Working Group believes that this budget by and large is carefully balanced and builds on the strategic plan which we endorse. In a few areas, notably the Shuttle Test of Relativity Experiment, the Earth probes line, and a program to fly instruments on international missions, modest increases in this budget could reap a very large scientific return.

We recognize that there are severe constraints on the federal budget. We also recognize that, in response to these constraints, this budget is very tight. We are very concerned lest programs be added to this budget without corresponding resources being added as well.

If the Advanced Communication Technology Satellite is added to the OSSA budget without corresponding resources, or if some of the other programs that I have mentioned are added without corresponding increases in funds, we would see further cuts into ongoing programs at OSSA, into our ability to carry out the strategic plan, and into this nation's return to a position of leadership in space science.

It is our view that we are poised on a threshold, a threshold toward recovery from what has been called a crisis in the Earth and space sciences and a return to an era of discovery and accomplishment the likes of which we have not seen for more than a decade. And with this budget we believe we can move confidently over that threshold.

Senator ROCKEFELLER. Thank you very much.

Let me ask you this. After 3 years of negotiations, the United States last September signed an inter-governmental agreement and memorandum of understanding with Canada, Japan, and the European Space Agency for the purpose of developing an international Space Station.

The foreign contribution to this program is estimated to be worth about $8 billion. It includes one polar platform to do Earth observations, one free-flying module to do automated research and experimentation, and two Space Station modules that will be used for life sciences and microgravity research.

What is the position of your respective advisory groups with regard to the importance of the Space Station program to the nation's leadership in space science? Does the science community support the Space Station? If for any reason the United States were to terminate the Space Station, would the U.S. be able to enlist the future economic and scientific support of other nations in cooperative space science activities?

And how important is international cooperation to the future of space science activities?

Dr. SOLOMON. Do you want to take that first?

Senator ROCKEFELLER. Either one.

Dr. LANZEROTTI. Initially, I will have to answer a little bit bureaucratically. The previous Space Science Board did not have the advisory responsibilities within the National Research Council for microgravity research and only had the responsibilities for life science. At the time the Space Station was being initiated, the previous Space Science Board found that for the science initiatives that had been proposed and the science strategies by the Board, the Space Station was not necessary to carry out most of them except for life sciences.

With our broadened responsibilities for space science and applications programs related to both microgravity and Earth remote sensing, the Space Studies Board now will look further at this issue.

There is no question but that the Space Station will have very definite and real possibilities for conducting life science research, both in fundamental biology, physiology and medical experiments, as well as in fundamental physics and chemistry and more material science research activities in a microgravity environment.

The Space Studies Board is presently formulating a subcommittee which will look much harder at the long-range scientific strategies in microgravity science that can be executed in a Space Station type of environment. We hope to be able to report back to this subcommittee and other Congressional groups in another year or so as to our findings in that matter.

In summary, the Space Science Board believed that for the scientific strategies related to astronomy and astrophysics and planetary exploration, the Space Station was not crucial for the execution of those strategies, but in terms of life science and in terms of microgravity science and applications the Space Station could make some real contributions.

I think what it boils down to is that those research activities, whether it be applications or science or an intermixing, that can best be carried out in a man-tended environment should be executed there, and those that do not require a man or man-tending should seek access to space by other means, namely expendable launch vehicles.

I believe the Space Studies Board still adheres to that position.

Dr. SOLOMON. Let me add a few remarks on behalf of the Space Science Working Group. We agree with many of the statements that Dr. Lanzerotti just made. Clearly, the space program and the

Space Station must be responsive to a number of national goals. The Space Station is not primarily a program to carry out space science.

Nonetheless, as has been mentioned, the Space Station will open a number of opportunities to carry out space science, particularly in Earth remote sensing, in life sciences, and in microgravity science. The space science community urges that sufficient attention and resources be given so as to maximize the scientific return from this facility.

We are certainly heartened by the international cooperative nature of the Space Station, and we see that as an example of expanding international cooperation on a number of international space science efforts across the board. The CRAF-Cassini mission which Dr. Fisk described has an essential component of cooperation, with the European Space Agency on Cassini and with West Germany on CRAF.

We are also endeavoring to cooperate more and more with the Japanese and with the Soviets, in terms of both sharing data and flying instruments on each other's spacecraft. The scientific community is looking to those cooperative ventures as opportunities to increase our ability to pursue new ideas.

In the Earth sciences, in particular, the distinction of national borders and national programs is going to blur. We live on one planet. We have to study it on a global basis, and the internationalization of space sciences we think will be very natural and very healthy.

So to the extent that the Space Station program can facilitate additional international cooperation across the space sciences, we are very supportive.

Senator BRYAN. Thank you very much, Dr. Solomon.

Senator Danforth.

Senator DANFORTH. Thank you, Mr. Chairman.

I want to ask this question to Dr. Solomon, although possibly Dr. Lanzerotti would want to make comments of his own. The question is what is the relationship, if any, between what goes on at NASA and what goes on in the universities.

Specifically, what does this mean with respect to the capital needs of the universities?

Now, my guess would be that if in fact we are looking at the possibility of a revolution in understanding the universe, if Dr. Fisk has indicated that in the next decade there is going to be a revolution in astrophysics, my guess is that that revolution would be experienced in the universities.

My further guess is that what goes on in the universities is not just a few people sitting around with pads of paper and pencils, but that science does have a peculiar claim for capital, for buildings, for equipment.

And my question to you is, are we prepared for the revolution? Is there a relationship between research that is done at NASA and research that is done in the universities? And should we as a country, and particularly those of us in Congress, be attentive not only to how much we are spending for NASA, but to the ability of our universities, particularly our research universities, to integrate their activities with whatever is coming out of NASA?

Dr. SOLOMON. Let me see if I can address that complex set of issues. The universities, though in many ways partners to NASA laboratories in carrying out space science, have in other respects a unique role to play, primarily through the training of students and through the nurturing of young investigators and postdoctoral researchers.

And in that capacity, it is clear that they need the facilities to carry out that kind of job. Such facilities, sometimes called infrastructure, include laboratories and equipment, both for teaching and for research.

As the space program recovers, as space science enjoys the kind of renewal you spoke of, we have to build on that recovery. We have to take advantage of the revolution that is going to attract the curiosity and the fascination of our youth, and we have to be ready to capture that enthusiasm and direct the new disciples toward careers in science and technology, and in the space sciences in particular.

The universities are prepared to invest some of their own resources in that direction, but they are going to be looking for NASA to help them out, particularly for new equipment and for expansion of such programs as the fellowship program.

Let me just give one example which was mentioned to me yesterday by a colleague of how NASA and universities in fact work together. One of the opportunities for flying U.S. experiments on international missions of opportunity that has excited the astrophysical community is a Soviet X-ray satellite called Spectrum X. OSSA is looking for ways to fund as many as three U.S. experiments to fly on that spacecraft that would complement the Soviet experiments and would get us back on the map in X-ray astronomy even before AXAF gets off the launch pad.

There may or may not be the resources to fly these three instruments, but all three of them involve cooperation between university investigators and NASA center investigators. This kind of synergism illustrates that universities do considerably more than just provide graduate students to eventually fill the jobs that are going to open up at NASA centers. There is a real exchange of expertise and communication about science and how to get things done and how to carry out experiments.

We look for a continued close cooperation between universities and NASA, the kinds of activities that are beginning to be fostered by the NASA graduate fellowship program, the kinds of collaborations that are happening naturally between individual scientists, and the continued support of NASA for those kinds of efforts at universities.

Senator DANFORTH. Of course, the budget is going to be a long-term problem for direct government spending. The universities are going to have to raise considerable amounts of money themselves.

During the 1986 Tax Act we did a couple of things to universities. We placed a cap on tax-exempt borrowing. We brought gifts of appreciated property under the alternative minimum tax.

Some university presidents and most particularly the AAU have made a very strong case that we have done serious damage especially to research universities. It is one thing just to make that assertion. It is another thing to bring it home by indicating that there are certain fields where the capital needs are going to be quite great.

I do not know whether your field is one which is capital intensive or not. But that really was the thrust of my question. Should we be concerned about what we have done to universities, and are we on the brink now of significant capital needs, not just hiring personnel but capital expenditures by research universities?

Dr. SOLOMON. Most of the facilities which house space science efforts at universities were probably built in the 1960's, the heyday of space science. Many of the buildings in fact were constructed at least partially with NASA funds.

Much of the equipment that is used in space science is very expensive, varying from analytical laboratories to facilities like telescopes. Very few of these facilities are being built nowadays. Some new telescopes are under construction, although all with private funds.

Many of the laboratories and many of the instrumentation groups that in the past successfully proposed new spacecraft instruments are dealing with equipment that is as much as 20 years old. It is a serious source of concern, and in many ways it is making the universities less competitive than their counterparts at NASA laboratories in devising creative new experiments and making use of the opportunities provided by new spacecraft missions.

Many of the universities are embarking on capital campaigns to raise funds for new buildings. But it is harder to raise funds for laboratory equipment, and harder still to keep highly trained technical groups together. That is an area where NASA has in the past fallen short of sustaining the kind of effort that they were able to maintain in the 1960's and the early seventies.

Unless some attention is redevoted to this issue, universities are not going to be able to capitalize on the revolution of which you spoke and are not going to be able to provide training at the state of the art to the new students who would otherwise be attracted to this field. This is a serious issue, and I would hope that NASA and the Congress can devote some attention to it.

Senator DANFORTH. One of the temptations that Congress gets into when we get into direct spending for research is that, particularly in the Appropriations Committee and then out on the floor of the Senate, it is a mad scramble for who can do what for institutions in his own state.

I take it that with respect to your field this is not an egalitarian enterprise. There are some people and some faculties and some institutions and some facilities where this is done particularly well. And there are others where either nothing is going on or not much of quality is going on.

And if the government of the United States gets into the business of spending money for space research, there are wise ways to do it and unwise ways. I think that it is really very sad and a frittering away of limited resources if we deal with this as a matter of just pleasing our own constituents.

Senator DANFORTH. I do not know if you have a response to that.

Dr. SOLOMON. I agree with your sentiment. It is true that not every university has devoted resources to building up strength in the space sciences. Space science is concentrated at a number of universities, and while that number is large, not every locality or every district has a college or university with a strong effort.

But from a national perspective, the expertise in the space sciences is a national resource. We would do well to make the most use of that resource.

Senator **Danforth**. Do you have any comments on any of these questions?

Dr. **Lanzerotti**. I have a couple of points that I could perhaps introduce from my personal perspective, coming from industry as well as a collaborator with university colleagues and as chairman of the Space Studies Board.

The United States is unique among the space-faring nations of the world in that our major space research effort, in the space sciences, is centered in our universities. That means that changes in that environment, whether it be problems with launch or large budgetary fluctuations or small budgetary fluctuations, have a more disproportionate impact on our capabilities for having a forward-looking program than they do in some of the other nations where the activities are primarily carried out by governmental laboratories.

Therefore it is very important that we pay careful attention to the health of our university infrastructure for carrying out space research in the United States. Now, whether that means capital or people or students or whatever needs to be discussed.

But my blanket statement is that the differences between this nation's space endeavors that we have established over the last 30 or 40 years are fundamentally different and need to be addressed in a different way than other nations do.

With regard to capital expenditures in the universities, particularly those related to space research, I personally believe and I think my university colleagues, would agree with this statement—to some extent—that much of the equipment that is needed is becoming quite major for doing many of the activities. There probably needs to be some consideration for the cross-institutional utilization of some of the equipment, whether they be supercomputers or specialized techniques for analyses of samples or building equipment.

It also requires—and by cross-institutional, I mean not only amongst universities, neighboring or distant, but also between universities and NASA centers. I believe there could be additional creativity on the part of NASA to foster the university utilization of unique equipment, whether they be centered at a NASA center or within a specialized university environment.

There probably has not been as much of that creative management on the part of the agency at times in the past as is warranted.

After all, not every university has a high energy particle accelerator. In fact, there are only about six in the world now. But when I was a graduate student some 30 or 40 years ago, there were many particle accelerators at many universities. Now there are centers of expertise and other universities use a national center.

I do not advocate this for space research. I do not think that is going to happen in most areas. But those areas where unique pieces of equipment are needed or unique facilities are needed for construction of equipment or for handling data, there should be more of a collaboration between universities and centers and universities and industry where that is appropriate.

Those are the two observations I would like to make.

Senator DANFORTH. Thank you.

Senator BRYAN. Dr. Lanzerotti, several years ago you chaired an advisory committee and your committee issued a report, "The crisis in Space and Earth Science." And the thrust of that report indicated that there were dire deficiencies and some serious concerns in the Nation's space science program.

Could you give us an update on your assessment? Have things improved, or are they about the same? Or maybe I have characterized the thrust of the report inappropriately, but if you would please give us your current, assessment?

Dr. LANZEROTTI. Yes, I will. The report was entitled, "Crisis in Space and Earth Science." It was written with a long background of the directions of our national program at the time.

There is not enough time available to address each of the major policy issues that we thought there were some crises in so let me just mention several of them and make some assessment.

I am recalling this from some memory now.

One of the major policy issues was access to space—the way by which the nation decided to access space and the kinds of techniques that we bring to bear for various science and technology programs. I believe that there is reason for considerable optimism now that the nation sees that the policy of a single launch vehicle was a faulted policy.

There is a fault. It is a faulted policy, but I would want to quickly say that it is not the fault of any one or any one agency or any one individual. It is just a fault of the nation in not being aware of that.

I think we are making real progress in that area, and I look for that to continue. As I said in my opening statement, however, I want to say that, while I think we are making real progress, I believe that several years down the road there will be some serious questions about whether we have a launch capability necessary to carry out the ambitious program in science and applications as well as constructing the Space Station that we have planned. I think this needs attention now in order to address that for the future.

Also in that report, we said that there were crises in terms of the infrastructure. We addressed the universities and we addressed this issue of the institutional balance between universities, NASA centers, and industry. Again, I believe there is some reason for cautious optimism here.

But as the question by Senator Danforth, Sean's statement and several points that I made illustrated, I believe that we have to be particularly careful. That is a hard one to address. It raises many issues, and I do not think we have addressed that quite as fully as we have.

However, the NASA budget request for OSSA this year, is very strong in terms of research and analysis and the underpinnings, and we need to see that that kind of emphasis continues.

We also called attention in that report to the growth of big science in the space sciences to the fact that there was a lien or there was a request on the budget by other elements, they are new players in the—if I can recall the terminology, they new players in the league maybe, the new teams in the league.

We characterized life sciences and microgravity research as the major new teams in the league. These areas of research are beginning to see the opportunities that a microgravity environment will provide for carrying out some fundamental research, as well as applications. This therefore places a lien by making additional requests in the budget that could cause budgetary stress.

I believe that NASA and OSSA in particular is very sensitive to that, and I have reason for cautious optimism here as well.

As I mentioned before this unique role that the universities have in the United States compared to other nations, as to how they play in this environment of big science, where telescopes are very expensive and there are vast data bases, and how the universities interface with these data bases and with constructing new instruments, is one that remains a concern to me personally and I believe to the universities as well. I think this is something we need to continue working on.

Those are three or four of the things from that report that I remember. My overall impression is that I have optimism, cautious optimism because of prior history, but cautious optimism that we are pointed in the right direction for a successful future, I hope.

Senator **Bryan**. Dr. Solomon, would you care to respond?

Dr. **Solomon**. Certainly. I think I share Dr. Lanzerotti's cautious optimism. Compared to the time when that report was being written and was completed, we have seen, with Len Fisk coming to OSSA, a strategic plan that in a real sense is responsive to Dr. Lanzerotti's report.

We see a very healthy balance between programs large and small. We see a move toward a diversified fleet of launch vehicles, to an orderly progression of new starts of various sizes, and to an attempt to reinvigorate the kinds of infrastructure elements that Dr. Lanzerotti spoke about, including the universities and graduate student programs.

So we are better off than we were when that report was written, but we still have a way to go. And in the context of these very long cycles we have seen in our space program, with bursts of accomplishment followed by long hiatuses with no new data, we need to be vigilant against a future recurrence of the kind of limited space program we saw in the early part of this decade. We need a healthy mix of planning efforts, advanced technology development and continued nurturing of new ideas at the same time we are carrying out ongoing programs.

Senator **Bryan**. I appreciate your comment.

Let me ask you first, Dr. Solomon, and then for you to respond as well, Dr. Lanzerotti. There seems to be a unanimity of opinion that America does not do as well in terms of its student achievement levels in the field of science as some of our competitors, not only in space, but in commerce and science and technology generally.

And I think it is fair to say that there is a growing consensus that we are not attracting a sufficient number of young people into these programs at the university and the subsequent graduate level programs that follow thereafter.

Specifically, what do we in the Congress need to do, if anything, to address this issue?

Dr. SOLOMON. Well, that is a pretty wide-ranging question.

Senator BRYAN. So often the Congress responds, Dr. Solomon, as you know, we respond and we rush forward, and sometimes our best-laid efforts, well-intentioned though they may be, miss the mark.

I am just asking you, as one who heads up this Space Science Working Group, where do you see our role? What can we do?

Dr. SOLOMON. I suspect—and this is outside of my area of expertise——

Senator BRYAN. Venture forth, venture forth.

Dr. SOLOMON [continuing]. That there are some things that Congress can do at educational levels below universities that are going to be very important within the context of what we are discussing today.

To attract more of the best young people into the space sciences, we need a very visible and sustained space program, because the kinds of things that our astronaut corps do, the kinds of things that unmanned missions of discovery do, truly capture the imagination of our youth, their curiosity, and their potential interest in things technical.

And one of the best things we can do to continue to draw the attention of our very youngest school children toward things scientific and technical is to have a visible and successful space program.

At the same time, we need a long-term commitment to programs to convince these young people that there is a career in the sciences and in technology, that the government has laid out imaginative long-term goals and that Congress and the executive branch are committed to a continuity of programs to achieve those goals, a continuity of programs that can draw the attention of enthusiastic and technically skilled young people and can show them that there is a place for them in these kinds of activities.

So, many of the things we are doing now in space we need to sustain and to build upon, over a very long term.

Senator BRYAN. Do you have an impression, before I turn to Dr. Lanzerotti to respond to the same general question, do you have a sense we are doing enough at the university level in terms of scholarship assistance, grants, loan programs and that sort of thing?

I am a little bit like Dr. Fisk. I have two children in school, one in medical school, one in undergraduate, and one who is about to go to law school. So I understand that there is just an enormous cost, you know, even for families that are clearly in the middle class income bracket.

Are we doing enough? Is that a handicap for us? Do we need to target more in that area, specifically in the areas of not just space, but what I would call science, math, engineering, the technical fields?

Dr. SOLOMON. There is no question that we as a nation could do more to encourage people at the undergraduate level to enter technical fields, and the financial obstacles are serious and are growing.

NASA, of course, has at the graduate level a fellowship program, which we applaud. It supports currently about 250 graduate students who are working in space science areas. It is very much an oversubscribed program. There are many talented people that apply for those fellowships that are turned away, though qualified, simply because the resources do not meet the demand.

It is a very modest program, but one which has been quite effective at attracting graduates from undergraduate schools into the space sciences.

Senator BRYAN. Worthy of being expanded in your judgment?

Dr. SOLOMON. Yes.

Senator BRYAN. Dr. Lanzerotti, your comments?

Dr. LANZEROTTI. I am going to speak from the perspective of a parent with two children at major research universities and also a member of our local school board. We just had a school board meeting last night which lasted until 11:30, and one of the points of discussion there was the fact that our algebra teacher is pregnant and has resigned, and how do we fill in our algebra class for the rest of the year and who do we hire as an algebra teacher next year.

Dr. Fisk, who I have known for many, many years and have a high respect for his scientific abilities and now his managerial abilities, related to us how he has a problem hiring somebody to head his microgravity research program. But you can imagine how hard it is for us to hire an algebra teacher, and we are looking for an algebra teacher who can perhaps teach physical science to some extent—we have a very small school district—when the pay scale for algebra teachers is really not very high, and we are limited by the union pay scales to not give very much incremental salaries.

So my 7 years on the school board, most of which have been as vice president—I have stepped down this year, last night at the reorganization meeting; I just do not have time to be a vice president any more—has given me a unique perspective and prejudices as to some of the educational problems in this country.

I think in terms of high school and elementary school education, we need a respect for teachers in the United States. We need a continual advocacy by our political bodies of the cultural and intellectual importance of respect for teachers and what they do.

We need a higher pay scale for educators in the elementary school and in the high school, to attract the best and to keep the best. We need a pay scale which can differentiate between the best and those who are not the best. And we need to work on that carefully between the school boards and the teachers unions.

We need a culture in the country for intellectual endeavors, which we do not have in my estimation and in my talking to the teachers and to the students in our school district.

Scientists and engineers tend to be intellectually oriented. It is not to say that the rest of the country is not. But to do science and engineering means that one year's course in college or in grade school or in high school builds upon another. If a student is lost in algebra this year in my local township, that student will not do calculus in high school and will not do differential equations in college.

It is somewhat different in history. I can learn American history this year and European history next year, or I can learn European history this year and American history next year. In high school that makes a very big difference.

In the high school environment and in the junior high environment, if there is not a respect for intellectual endeavors at the equivalent level that we give to athletics and other extracurricular activities, the students will not be interested in putting in the efforts for those activities which build upon one another, algebra to calculus to differential equations.

And the same situation holds in the major research universities. The mentoring and advisory system in the major universities needs strengthening by the universities. They acknowledge this to some extent, but not at the extent which they need to devote.

The professors and the faculty need to devote much more attention to the mentoring and the advisory system for students enrolled in technology endeavors.

I think we have to work on all of these three or four things which I addressed in order to address some of the serious technological and engineering and scientific issues that face the United States. Money in the form of loans and grants and fellowships are one thing, but the culture of this country and the respect for teaching and intellectual endeavors and the mentoring is something that we cannot put a dollar value on very easily, but it is something that we need to address.

Senator **Bryan**. I appreciate your comment.

Let me just ask a last issue if I may. You have been very generous with your time and we appreciate it.

The New York Times on Sunday carried an article on the front page which you may have seen, and it addressed the risks that were involved in the shuttle. And it made a point which I think, Dr. Lanzerotti, you made during the course of your testimony or in response to one of the questions.

And the question is this: In terms of the kinds of experiments that need to be conducted in space, the kinds of loads that need to be launched to conduct this technology research, one of the points made in this article is that those things that do not require by their very nature humans in space ought to be launched by the ELV, as opposed to the shuttle. Obviously, there are things that require personnel in space to conduct those experiments.

My question is, has the agency generally in your judgment balanced those missions appropriately? That is to say, have we appropriately said," look, in this particular shuttle launch we can conduct certain types of experiments because those by their very nature require individual scientists or technicians, as opposed to other types of activities in space which can be launched and observed and monitored through telecommunications and do not require human beings to be on board, so to speak?

Dr. **Lanzerotti**. Well, to be quite frank, in previous years the answer to that is no. Otherwise we would not have been in the crisis. One of the major reasons for the crisis in space and Earth science was the reliance upon a single launch vehicle, which was, as I say, a faulted policy.

Senator **Bryan**. Yes, I think we all acknowledge that.

Dr. LANZEROTTI. I believe that the agency and the American people and their elected representatives have become much more conscious of that, and I think we as a nation are moving in the proper direction now.

I think the report in the Times reflects that, and in fact the sentences which you quoted, when I read that on Sunday in the Times I said, gee, this sounds like something that came out of our "Crisis in Earth Science" report that these people used. It was not particularly innovative by us, but almost the same phraseology that we used three or four years ago in that report.

I think the Nation is much more concerned about that now. There will be failures. Hopefully they will not be fatal of the nature of the Challenger, but we will have failures. We will have them in ELV's, we will have them in various manned exploration flights.

It is a high risk game we are playing. It is a high risk venture. Without risk there is no gain. The Soviets just suffered a tremendous loss in their high risk program.

But with all of our—but with a diversified research program in applications and in science, with a diversified launch policy, we will find in the future that the risk and the failure that we might suffer in one area will not completely devastate this very vital national initiative that we have ongoing.

Senator BRYAN. I take it implicit in your response is that it is an appropriate role for the Congress, as the space agency presents its programs to us for consideration and for approval, to ask the tough questions as to which of those programs are appropriately conducted without the added expense involved in a shuttle launch and the safety precautions which understandably are involved in that, as opposed to an ELV?

Is that not an appropriate role for the Congress?

Dr. LANZEROTTI. It certainly is, and I encourage it.

Senator BRYAN. Dr. Solomon, do you have any thoughts?

Dr. SOLOMON. I can only echo what Dr. Lanzerotti said. For many years we are going to continue to see the impact of NASA not making the kind of decisions of which you spoke. Later this year the Galileo mission is being launched. The spacecraft is going to swing-by Venus and then swing-by the Earth twice, for a total flight time in excess of six years. This trajectory is necessary because it is being launched on the shuttle and the Centaur upper stage was deemed too dangerous to go in the shuttle bay.

By the same token, because Galileo has to fly-by Venus in order to get out to Jupiter, the natural launch window for Magellan this year is taken. As a consequence, Magellan must take a trajectory that carries it entirely around the sun, with a 15-month passage instead of a 4-month trip time.

Both of these missions are thereby lengthened and made more risky and more costly, directly as a consequence of this one very erroneous decision to rely entirely on the shuttle for all space launches. Of course, NASA has since changed that decision, and we see new missions appropriately slated for unmanned launch vehicles, CRAF-Cassini being the latest example.

We have corrected our past mistake, but we are not going to reap all of the benefits of that correction for several years.

Senator **Bryan**. Gentlemen, I greatly appreciate your testimony, as I know Senator Rockefeller, who served as chairman today, and Senator Danforth and Senator Pressler and others who have been here have appreciated your testimony.

This subcommittee hearing is adjourned and the subcommittee stands in recess. Thank you very much.

[Whereupon, at 12:18 p.m., the subcommittee was adjourned.]

NASA AUTHORIZATION

THURSDAY, MAY 11, 1989

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology, and Space,
Washington, DC.

The subcommittee met at 9:35 a.m. in room SR–253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator Gore. The subcommittee will come to order.

I would like to give an extra warm welcome to our guest this morning, Admiral Truly.

It is the first time I have had a chance to sit here as the Subcommittee Chair with you across the table as Acting Administrator soon to be the confirmed Administrator.

You have already been welcomed and praised and all that, but I have not had a chance to, and so I want to welcome you myself.

I want to again express my thanks to my colleague, Senator Chuck Robb, for filling in for me in this chair when I was in the hospital helping to take care of my son after he was injured, and I appreciate Senator Robb's handling of that. And, as always, he did an outstanding job.

And, you know, while I was in, while my wife and I were there in the hospital with our son, the crew of the shuttle mission before this last one came to visit him, and I want to say again a word of thanks to them.

They took the extra time, Admiral, to go over to the children's cancer unit in the next building over at Johns Hopkins and really spent the better part of the day going around.

And I think the nurses and doctors were about as excited as the patients were. And it really did make for a bright day there.

And I want to welcome J.R. Thompson, who is here, who is a new member of the team or, rather, in a new capacity.

I want to welcome our other witnesses who will also be coming to the witness table and those who are accompanying you, Admiral Truly.

Today we are going to review the fiscal year 1990 budget request for space transportation and related policy issues. But first I want to compliment the men and women of NASA and the aerospace community and the respective advisory groups for their efforts in returning the space shuttle to flight status.

The completion of three successful space shuttle missions in the last seven months points to the return of the program and the restoration of safety and reliability as the hallmarks of NASA.

I think we have to have, as everyone I am sure recognizes, a continuing, unrelenting emphasis on safety. The recent studies about accident projections and probabilities again, while some dispute the details, underscore the need for an extra emphasis on safety.

The committee does look forward to acting, as I mentioned, on the nominations of Dick Truly and J.R. Thompson, and that is going to be done without delay. We are just making sure that the ducks are in a row administratively and we have talked privately about that. There is not going to be any delay at all.

When do you take over, admiral? Are you sort of officially acting administrator next Monday?

Admiral Truly. That is right, next Monday. Well, today. Tomorrow Mr. Dale Meyers, who is the Deputy Administrator of NASA, will be—this will be his last day in our normal internal chain of succession. I will be next and so, come Monday, I will be the Acting Administrator awaiting confirmation from the Senate.

Senator Gore. Well, I think I can speak for the other members of the subcommittee in their urging you to make an active, aggressive effort to make the appointments you need pending the formal completion of your confirmation process. You just go right ahead and move swiftly because there is not any doubt about what is going to happen in the confirmation.

Admiral Truly. Thank you, Mr. Chairman.

Senator Gore. I also want to say that we have an ambitious agenda in this hearing. We intend to review the budget request for the Office of Space Flight to make sure you have the resources required to maintain a safe and reliable space transportation system and to support the sustaining engineering and systems upgrade required to maintain that system.

I am concerned that the fiscal year 1990 Office of Space Flight budget request was cut $329 million by OMB and that a space shuttle flight was cancelled to ensure adequate reserves in fiscal year 1990.

I am also concerned about the personnel situation in this program area in light of the major initiatives proposed or being contemplated by NASA, including the advance solid rocket motor, the crew emergency rescue vehicle, Shuttle C, a personnel launch system, and the advanced launch system.

Good people are a precious commodity, and I am fearful the enactment by Congress of the ethics bill and rejection of the pay raise may have cost us some good people. We saw a seemingly mass exodus that was never intended by anybody acting on these measures.

Besides budget matters, the subcommittee would like to explore a variety of policy matters including an in-depth discussion of the proposed advanced solid rocket motor (ASRM) facility.

I have long been and continue to be an advocate of the ASRM program. However, when I became Chairman of the subcommittee, I promised to deal openly and directly with an extra measure of attention anytime there were safety-related issues. Today I intend to keep that pledge and to provide a forum for a thorough discussion of the issues related to the development of an ASRM, and I have invited other Senators with an interest in this question who are not members of this subcommittee to join us in that thorough discussion.

Included in this discussion will be an assessment of the proposed financing scheme for the new ASRM facility in Yellowcreek, Mississippi. I should indicate that I am somewhat skeptical of private sector financing schemes in these areas, and of costly lease purchase agreements. However, in this instance a very clever deferred principal payment mechanism puts this proposal on an equal footing with traditional government financing and helps alleviate the fiscal year 1990 budget crunch.

So, this proposal does, I think, warrant very serious consideration by the subcommittee, as does the Heflin contingent liability bill, S. 663 that would give NASA the legislative authority required to implement this innovative financing scheme.

Well, rather than consume any more of our time, let me just open it up, first of all, to Senator Robb, if you have any kind of a statement to start off here.

Senator ROBB. Mr. Chairman, I am not going to have any opening statement at this time. I look forward to hearing the testimony.

Senator GORE. All right. Very good. We will go to our first witness.

I have a statement for the record from Senator Hollings.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

Over the course of the last few months, the Subcommittee on Science, Technology, and Space has spent considerable time discussing the challenging missions that NASA hopes to implement during the next decade. Discussions have focused on everything from the explorer program to microgravity research, from the Mission to Planet Earth to the space station program.

Today, the Subcommittee will discuss the budget request for the Office of Space Flight, the trucking firm on which all of these proposed missions depend.

In the course of our discussions, we will try to determine if NASA has the resources required to maintain a safe and reliable space shuttle and to support a mixed fleet. We will explore ongoing and proposed upgrades and improvements to the space shuttle system and the proposed test regime. We will assess NASA's response to the recommendations of the Stever Commission, and we will assess the findings and recommendations of the NASA Aerospace Safety Advisory Panel.

In addition to our budget review, the Subcommittee will explore a variety of policy matters including the proposed private sector financing of the advanced solid rocket motor facility in Yellow Creek, Mississippi. As one who was intimately involved with the decision to initiate an advanced solid rocket motor, I can assure everyone that that decision was based on the enhanced safety and reliability such a motor would provide the space shuttle. The additional performance was an added benefit—but not the principal benefit.

I am concerned with the reservations being expressed by the Aerospace Safety Advisory Panel and hope that today's discussion will resolve this matter once and for all.

I would like to thank our distinguished witnesses for their participation in today's hearing and for their efforts on behalf of the Nation's space program.

Senator GORE. I understand that you are the only witness at the table who will give us a prepared statement, but your associates are available to answer questions if needed.

And could you introduce the rest of the panel, Admiral Truly, and then without objection, Your full statement will be put in the record, and you can proceed with a summary or a full presentation, just however you see fit.

But, start off by introducing your colleagues.

STATEMENT OF ADM. RICHARD H. TRULY, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY ARNOLD ALDRICH, DIRECTOR, SPACE SHUTTLE PROGRAM; JOSEPH MAHON, DEPUTY FOR FLIGHT SYSTEMS; AND LOWELL ZOLLER, CHAIRMAN, SOURCE EVALUATION BOARD, MARSHALL SPACE FLIGHT CENTER, AL

Admiral TRULY. Thank you, Mr. Chairman. I appreciate the opportunity to introduce the people I do have at the table because they have brought the Office of Space Flight to the position that I believe we will be able to try to answer your questions today.

To my right and your left is Mr. Arnie Aldrich, who is the Director of the Space Shuttle Program and has led the space shuttle recovery team since the days immediately following the Challenger accident. And the country, I believe, owes Arnie a real tribute and thanks.

To my immediate left is my Deputy for Flight Systems, Mr. Joe Mahon. Joe is responsible for our mixed fleet, our expendable launch vehicles and also our inertial upper stages that have put three of the last four shuttle missions in orbit successfully. And Joe is my Deputy for Flight Systems.

And because of your interest, the interest of the subcommittee on the advanced solid rocket motor, I have invited for the first part of this hearing today, Mr. Lowell Zoller, who is Chairman of the Source Evaluation Board at the Marshall Space Flight Center that evaluated the proposals and is expert on particularly—not only on the evaluation itself which we conducted, but also on the financing. So, I think we will be able to answer your questions.

You mentioned Mr. J. R. Thompson. He is here, and in the second part of your hearing today, he will be joining us with your hearing with us and the members of the Aerospace Safety Advisory Panel.

Let me say right up front that I am extremely pleased to be here to represent the Office of Space Flight, and I would like to submit my written remarks for the record.

Today culminates three years that I have been coming to this committee in this capacity as Office of Space Flight, and if I am confirmed by the Senate, I look forward to coming in future years in a different capacity.

But I believe that in these three years, starting right after the Challenger accident, much has been accomplished. It has been an arduous job in rebuilding. We have taken the space shuttle program back to the basics from the top to the bottom.

When I was here last year we had not started flying again, and I projected that we intended to put first a tracking data relay satellite in geostationary orbit.

Then our most previous DOD national security mission accomplished that. Finally, complete the TDRS constellation and still arrive early in the Magellan launch window to send Magellan to the planet Venus. We did it last Thursday night in Houston.

I was plugged in in the back room and listening to the inertial upper stage firing that only lasted over a period—within 10 minutes we fired both the first and second stages, and I heard a young lady on the loop say Magellan control, "Houston, you are on a hyperbolic trajectory to Venus." And I am pleased to say that here today that was less than a week ago today.

Today the Atlantis is back. She came back as safe and as clean as any vehicle that I have seen. Very little tile damage. Minimal failures on orbit, and her next job is to—we are going to load her up with Galileo on October the 12th. We intend to be early in that launch window to send Galileo to the planet Jupiter.

Senator GORE. If I could interject, I look forward to joining you before October, on August 25th in Pasadena for the first encounter of humankind with the planet Neptune when the pictures will come across the screen from Voyager. That will be—although that program was started so long ago and has had such a heroic journey through our solar system, that should be added to the calendar of exciting accomplishments of NASA throughout the remainder of this year.

Admiral TRULY. I agree, and I will be there with you. It will be an opportunity that will not reoccur in many of our lifetimes to see that Neptune Encounter as it is called.

Also yesterday the President announced that he had chosen the name Endeavor for the new orbiter that we are building in Palmdale, California. That orbiter was fully funded by the Congress in the fiscal year 1987 appropriation.

It is on schedule, it is under cost. It is going to roll out in Palmdale in the spring of 1991 and fly its first flight and join the orbiter fleet in the winter of 1991 and 1992.

We did more in 1988 since my last appearance here than shuttle flights. As a matter of fact, we not only flew two shuttle flights. NASA was eight for eight, six ELVs and two shuttle flights in 1988, all successful, all successful missions. And I am extremely pleased to say that we are aggressively pursuing this mixed fleet, a balance of the proper vehicles for the proper satellites, be they shuttles or expendable launch vehicles.

I attribute our status as they appear today for the technical and management structure that we put into place since the accident to the strong quality organization which I know you had a great interest in early on after the accident, and it has been headed up by Mr. George Rodney who will be joining NASA or earlier in this particular hearing.

George and I have worked shoulder to shoulder over the past three years, and not always agreed, but we always agreed on what the final result was to be, and that was to be a safe and reliable system. But most of all, to the outstanding people who have caused this recovery to happen. They exist coast to coast in our all our NASA facilities and installations and in our contractors'.

As a matter of fact, the Office of Space Flight represents almost 10,000—about 9,700 civil servants. And when you go through our prime contractors and our subcontractors, we provide about 45,000-50,000 jobs across this country, and they are some of America's best jobs. They are engineers, scientists, technicians, the kind of jobs that build communities across America.

So NASA, even though our accomplishments are in space, a lot of the payoff, I think, for the future of the country is here in America.

Our flight schedule illustrates how important space is to our country. We are here dealing with the fiscal year 1990 budget, but we normally put out a flight manifest for our total of five years in the future. And on that flight manifest for the Office of Space Flight are a little over 60 shuttle flights and about 29 ELV flights as we build up the mixed fleet over these years.

I am concerned about the level of funding, but I can assure this subcommittee that we will not back off on the infrastructure and the underpinnings that we put in the program to make it as a risk that we understand and that we are willing to take when we lift off.

Things have changed internationally also in the space launch business. When I first got into the space program as the other individuals at this table, it was the United States and the U.S.S.R. in the launch vehicle business both manned and unmanned.

Today the world has changed. European nations, Japan, China, the Soviet Union, are all in competition with each other in the launch vehicle business, and I believe in our country that we cannot take this part of the space business for granted. Therefore, we are looking to the future.

We, both in our manned systems and improvements in the space shuttle, including the advanced solid rocket motor, but also looking farther beyond the space shuttle in the Office of Space Flight, we have studies going on to make sure that we are positioned with technology which takes a long time to develop in order to work that and so we, in addition to the things that you see today, we are a government agency.

And in the Office of Space Flight are one that we really sit around the table and talk about America's space program 20 years, 30 years, 50 years from now.

It is a fun business, but it is one that does require that underlying funding of technology, materials, new engines, etcetera, and we are doing that.

I would like to also say at the end, however, that—and remind myself and all of us here—that spaceflight as well as we are doing cannot be made risk-free. We cannot lift off, we cannot fly in space with a perfectly safe system.

We absolutely have to assess risks, and we have put a process in place to do that. I am confident that we have done everything we can to take what is the prudent—to taking the risk out of the space shuttle program.

We have flown four excellent flights. We have many of them ahead of us, a lot of work to do. But, the reason that the risk is worth taking at the end, after we understand it, is simply because the achievement for our country in technology and in space science and in other parts of NASA in quality aeronautics is worth that risk.

So, in summary, Mr. Chairman, we in the Office of Space Flight in NASA need your help and your support. I personally believe that our country's future rests on our investments in science and technology that NASA represents in both aeronautics and in spaceflight, and in NASA's variability to fly in space rests in the Office of Space Flight and in this budget before you today.

Our shuttles, our mixed fleet, our upper stages require continuing support for us to be able to have this major national program.

Finally, the fiscal year 1990 budget, I believe, is adequate for the task at hand to fly the flights in 1990 and to buy those tanks and rockets for the flights that the 1990 budget supports in 1991 and out, but I can tell you that the budget submitted to you is tight as a drumhead.

It has been looked at over and over again internally, and I believe it is adequate. As a matter of fact, we scrubbed it so hard that we actually did take a flight out of 1990 for budgetary reasons even though we felt that we had the capacity to do it in order to put together the total NASA budget.

So, Mr. Chairman, I hope I did not go on too long, but we are proud of what we have accomplished in the last year since we have been to this subcommittee, and we are pleased to be here, and I hope to have the opportunity to try to answer any and all of your questions today.

[The statement and questions and answers follow:]

Statement of

Richard H. Truly
Associate Administrator
Office of Space Flight

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee:

I welcome this opportunity to review with you the programs of the Office of Space Flight (OSF). I would like to review the significant achievements and progress we made in 1988 and early 1989, highlight concerns I have about the challenges we face this year and beyond, and outline the OSF's Fiscal Year 1990 budget request.

Let me first note a few essentials:

- **The Shuttle does many jobs--all of them well.** Our 1988 launch record was 100 percent--eight successes! Six missions used Expendable Launch Vehicles (ELVs) and, most significantly, we safely returned the Space Shuttle to flight status with two outstanding missions. In 1989, the Shuttle program has continued its achievements: the Discovery delivered another Tracking and Data Relay Satellite (TDRS) to orbit; and, just last week, Atlantis sent the Magellan spacecraft on its journey to Venus. The Shuttle enables the United States to dramatically expand our capabilities in space with the men and women who bring to Earth orbit creativity, imagination, and dexterity.

- **Our successes are a direct result of the technical and management structure and process we have put in place.** This, along with our rigorous test and qualification program, has been key to our achievements. The real challenge for us all, as flight rate increases, is to properly fund and maintain this activity and organization; we must forever avoid complacency and insure the clear delineation of responsibility and attention to detail.

- **NASA's mixed fleet strategy is being implemented with vigor.** The mixed fleet combines Space Shuttle flights with unmanned launch services obtained from the commercial sector to provide the best transportation balance for the civil space program. Only where commercial launch services are not available do we procure unmanned vehicles through the Department of Defense (DOD).

- **NASA's flight schedule illustrates how vital space is to our country.** NASA's flight schedule for the Space Shuttle missions through FY 1994 numbers over 60 Shuttle launches. Our unmanned launch vehicle programs encompass 29 launches during this same period. This situation challenges us technically, operationally, and fiscally.

- **Our program successes continue to require a strong institutional base.** Some 9,700 civil servants plus associated support contractors constitute the real strength of the OSF. Meeting our institutional requirements (quality people and good facilities they can work in) continues to be a management challenge.

- **American leadership in space transportation cannot be taken for granted.** International competition has become intense. The United States must invest in new technologies and new systems to meet national objectives as we approach the twenty-first century. The international competitors are continuing to develop their capabilities.

- **Durable as they are, the current Shuttle fleet will not last forever.** In the twenty-first century, improvements in space transportation will be required to support our evolving national requirements, such as the long-term goal of expanding human presence and activity in space. It will take at least ten years to design and build new systems if required. It is timely now to begin thinking conceptually about what is needed and our options for the future.

- **Finally, space flight cannot be made risk free.** The return-to-flight program has allowed NASA to assess and better understand the nature of the risk, then reduce it to prudent and acceptable dimensions. I am very comfortable that we have struck a good balance, and we pledge to maintain safe and sustainable operations as we increase the flight rate to support the nation's civil space operational requirements.

We have undergone a major transition in the past three years. The OSF and its programs are vastly improved from the standpoint of structure and procedures. In January we completed the final full-scale test of the Redesigned Solid Rocket Motor (RSRM). Throughout the ground tests, and on the four Shuttle flights in the past year, the redesigned hardware performed as predicted. Those flights, and the six successful ELV flights of 1988, have reassured us that we are on the right path. We all recognize, however, that a great deal remains to be done. In that spirit, we seek your support in sustaining in FY 1990 the momentum that we have accumulated and are so proud of.

I would now like to review our FY 1990 budget request:

OSF FY 1990 BUDGET REQUEST

The OSF FY 1990 budget request is $4,676.5 million. We request $4,037.5 million under Space Flight, Control and Data Communications (SFC&DC) and $639 million for Capability Development, funded under the Research and Development appropriation. The SFC&DC request is divided into two elements--$2,732.2 million for Space Transportation Operations and $1,305.3 million for Shuttle Production and Operational Capability. Programs and activities funded under these categories are:

- SPACE TRANSPORTATION OPERATIONS -- supports Shuttle Flight Operations, Flight Hardware, and Launch and Landing Operations, as well as procurement of Expendable Launch Vehicles and Services.
- SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY -- provides the capability to fly safely at the projected flight rates. Funding is identified separately in Orbiter Operational Capability, Propulsion Systems, and Launch and Mission Support.
- SPACE TRANSPORTATION CAPABILITY DEVELOPMENT -- provides for effective use of and improvements to operational capabilities. Funding is included for Spacelab development and operations, upper stages for both the Shuttle and ELVs, the necessary Engineering and Technical Base, Payload Operations and Support Equipment, and studies of new capabilities including Advanced Programs and Advanced Launch System (ALS), as well as development of the Tethered Satellite System (TSS) and the Orbital Maneuvering Vehicle (OMV).

To put this request in the proper context, a discussion of our flight manifest is in order.

NASA's FLIGHT MANIFEST

In the past three years, you have watched the NASA mixed fleet manifest mature. The Shuttle projected flight rates have stabilized at five to nine per year in FY 1989-1991, increasing to 14 in FY 1993 after the new orbiter begins operation in 1992. The ELV flight rate averages about five per year. Payload programs have adjusted their schedules and budgets to match flight opportunities.

Our most recent manifest covers the years FY 1989-1994 and includes flights (for NASA, NOAA, international customers, and DOD) on Shuttle and ELVs. It shows the accommodation of 29 spacecraft on ELVs and 129 payloads on Shuttle. These flights represent the full range of space program objectives--national defense, astronomy, astrophysics, earth sciences, planetary exploration, life sciences, microgravity materials research, communications, weather observations, navigation, advances in space technology, and the expansion of human presence in space. A number of payloads directly support commercial initiatives in space.

Studies are under way to define the best manifest balance (manned and unmanned) for the challenging years beyond FY 1994 when we will assemble, build, and operate Space Station Freedom.

SPACE TRANSPORTATION OPERATIONS

Of the $2,732.2 million requested for Space Transportation Operations, $772.6 million is for Shuttle Flight Operations, $1,236.5 million for Flight Hardware, $553.6 million for Launch and Landing Operations, and $169.5 million for Expendable Launch Vehicles and Services.

Flight Operations

Flight Operations supports the planning and control for each Shuttle flight for which we request $772.6 million in FY 1990. In the mission support area, preflight mission planning, training, and operations control activities are provided. Tasks include flight planning, systems and software handbook preparation, flight rules and procedures, Mission Control Center (MCC) and network requirements, and operations planning for selection and operation of Shuttle payloads. Also included are the maintenance and operation of critical facilities such as the MCC, Shuttle mission simulator, and the software verification facilities.

Integration includes orbiter sustaining engineering, payload and system integration, launch support services, and development and verification software. Sustaining engineering provides prime contractor engineering activities necessary to qualify the orbiter for flight, as well as flight verification and analysis tasks. Orbiter software activities include development, formulation, and verification support, plus base operations support at our field centers. Base operations provides orbiter engineering and support, crew equipment, flight operations systems, and support to the Space Shuttle program office, plus aircraft operations.

Flight Hardware

The FY 1990 request of $1,236.5 million is directly related to the Shuttle flight rate. This includes orbiter spare parts, replacement of consumed hardware, repair and logistics operations, maintenance schedules, and operational usage, taking into account lead times to procure or repair flight hardware. The budget provides replenishment, line and shop replaceable units, plus the manpower to support the overhaul and repair activity for the orbiter, extravehicular maneuvering unit, and other crew equipment. Funding also provides main engine refurbishment overhaul, as well as replenishment or repair of engine component spares and flight support.

Flight Hardware provides the Solid Rocket Booster (SRB) and External Tank (ET) requirements including major element and materials procurement and labor for required refurbishment and manufacturing. The SRB project will deliver six flight sets in FY 1989 and nine in FY 1990. The ET will remain at the minimum delivery schedule of four tanks per year through FY 1990. These projects have extended manufacturing cycles and long-lead materials procurements. As a result, a significant part of FY 1990 funding supports the increased flight rates planned for subsequent years. The first flight support motor static firing test will be conducted in FY 1990 to monitor the consistency of RSRM production characteristics and to provide a continuing engineering data base to enhance program safety.

Launch and Landing Operations

The $553.6 million requested for Launch and Landing Operations provides manpower and support services necessary for processing launches. This includes SRB assembly, ET/SRB/orbiter mate, orbiter processing, integrated vehicle checkout through launch, SRB retrieval, and landings. Landing support includes safing and deservicing and downloading mission-unique experiments and payload carriers.

Expendable Launch Vehicles and Services

A two-phased plan to implement the mixed fleet ELV program is under way. In the first phase, four Shuttle payloads: Roentgen Satellite (ROSAT), Extreme Ultraviolet Explorer (EUVE), Combined Release and Radiation Effects Satellite (CRRES), and Mars Observer (MO), were transitioned to ELVs. In the second phase, NASA plans procurement of launch services directly from commercial ELV operators in three performance classes: small class (payloads up to 1,000 lbs. into low earth orbit); medium class (payloads up to 10,000 lbs.); and intermediate class (payloads up to 30,000 lbs.). NASA missions in the large performance class (payloads 40,000 lbs. or more) will continue to be acquired through the DOD, as launch services are not available from the private sector in this class.

The ELV budget request for FY 1990 is $169.5 million. FY 1990 funds will continue activity on the CRRES, MO, and EUVE missions; launch the ROSAT; continue procurement of commercial launch services for medium-class GEOTAIL, Polar WIND, and MSAT; and the small-class Office of Space Science and Applications Explorer missions. Initial mission integration activities for a Titan IV launch of CRAF and an intermediate-class launch of Solar Heliospheric Observer (SOHO) in 1995 will also be started.

In strong support of ELV commercialization, NASA negotiated and signed the nation's first commercial launch services contract in mid-1988 for a series of Geostationary Operational Environmental Satellite (GOES) missions. We also negotiated the government's first barter exchange of residual launch vehicle production and flight hardware assets for commercial launches for the Fleet Satellite Communications (FLTSATCOM-8) payload and CRRES. We are currently negotiating for a commercial Titan III for launch of the MO spacecraft in FY 1992.

During 1989 we will launch the Cosmic Background Explorer (COBE) mission. COBE will use funds reimbursed from residual Delta vehicle hardware. On Scout we will launch two Navy missions, MACSAT and SALT, and on Atlas/Centaur we will launch the last DOD FLTSATCOM payload. Activity continues on procurement of Delta IIs through the USAF for launch of the ROSAT and EUVE missions in FY 1990 and FY 1991. We plan to competitively select private sector operators to provide commercial launch services for our small and medium-class out-year missions.

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

The $1,305.3 million requested for Shuttle Production and Operational Capability is planned as follows: $237 million for Orbiter Operational Capability, $727.3 million for Propulsion Systems, and $341 million for Launch and Mission Support.

Orbiter Operational Capability

$157.5 million of this request will provide for completion of previously approved systems improvement programs, necessary safety modifications, and engineering analysis and integration capabilities to support the flight rate. Examples of improvements initiated even before the standdown are the star tracker, carbon brakes, and an improved inertial measurement unit, plus new general purpose computers which become operational in 1990.

The Extended Duration Orbiter (EDO) request is $25 million. We have initiated necessary work to provide the capability of OV-102 (COLUMBIA) to stay on orbit up to 16 days. The EDO adds a cryogenic pallet for additional power generation and modifications of waste management and environmental control systems. We plan to "scar" the replacement orbiter, OV-105, as it is being manufactured, to provide a backup to OV-102 and to enable progress beyond the 16-day capability. This program was initiated in FY 1988, and the FY 1990 request assumes private sector investments in the EDO program.

$30.3 million will provide ongoing procurement and fabrication of orbiter spares and a logistics system to support the operational flight rate. A logistics depot, established near the Kennedy Space Center (KSC) for repair and maintenance of flight and ground support hardware, will reduce costs and shorten turnaround time.

Funding for a set of structural spares to replace those used in the production of OV-105 was begun in FY 1989 and continues in FY 1990. These new structural spares provide a minimum capability to produce another orbiter, provide additional hardware for the logistics inventory, and provide for retention of orbiter contractor and subcontractor production support capabilities. NASA believes that augmentation of the $15.2M in the FY 1990 budget is desirable to support a robust and timely buildup of structural spares to effectively fulfill these objectives. Consequently, we are considering an augmentation of the FY 1990 structural spares funding from the OV-105 budget account. A careful review of OV-105 resources and work to complete indicates such a transfer could be accomplished while still maintaining adequate OV-105 reserves. NASA plans to request Congress to provide concurrence for this transfer.

A $9 million request for systems integration funds covers all redevelopment analyses and analysis of hardware changes, as well as development of a Systems Integrity and Assurance Program to provide management visibility into the critical parameters of hardware and systems performance.

Propulsion Systems

The FY 1990 request includes $496.6 million for the Space Shuttle Main Engine (SSME), which includes continued testing and evaluation of hardware as well as improvements to the current SSME. The SRB funding request of $106.7 million focuses on continued evaluation and analysis of flight data to assess the redesign, continued improvements to the Solid Rocket Motors (SRM) manufacturing process, and reclamation or replacement of pre-Challenger reusable hardware. The ET request of $2.7 million supports the hardware production with acquisition of off-the-shelf test and manufacturing support equipment.

The Advanced Solid Rocket Motor (ASRM) program will be funded at $121.3 million under this request. The ASRM will provide enhanced safety, reliability, and increased performance through the life of the Shuttle program. The Request for Proposal (RFP) for the ASRM development production phase was issued in August 1988, and a winning contractor team was selected, with contract award to follow. Under the ASRM acquisition plan submitted to the Congress on March 31, 1988, alternatives under consideration include methods to finance the facility through the private sector, but specifically retaining the government's ability to recompete the contract in future years.

Facility construction, motor design, and development of the new motor is planned to begin in FY 1989. The development program is anticipated to extend for five years, with the first flight in late 1994. The ASRM development rests on a far more mature technological base than that available in the 1970's at the start of the original SRM project.

Launch and Mission Support

$341 million is requested for Launch and Mission Support. This supports Johnson Space Center (JSC) mission operations capability development at $166.9 million and mission support capability items at $75.6 million. Major facility modifications and launch site equipment at KSC require $98.5 million to provide more efficient launch processing operations. The current Orbiter Maintenance and Refurbishment Facility is being upgraded to be a fully operational Orbiter Processing Facility by the fall of 1991, just prior to the fleet introduction of the replacement orbiter.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

Our FY 1990 request for Research and Development funds under Space Transportation Capability Development is $639 million. This amount supports $98.9 million for Spacelab, $88.6 million for Upper Stages, $189.8 million for Engineering and Technical Base, $81.1 million for Payload Operations and Support Equipment, $48.7 million for Advanced Programs, $5 million for ALS, $19.9 million for TSS, and $107 million for OMV.

Spacelab

The Spacelab request is $98.9 million in FY 1990 and will support flight opportunities created by an increase in the allowable orbiter downweight capability and a reduction in DOD flight requirements.

Preparations for NASA scientific, DOD (Starlab), and international missions are in process. The next NASA Spacelab mission, Astro-1, scheduled for mid-1990, will be the verification mission of the igloo pallet configuration. Additional flight hardware, direct mission and mission-related manpower, and payload operations control center activities are required to support the FY 1990 Space Life Sciences (SLS-1) and the FY 1991 (Atlas-1) missions.

Also scheduled during 1990 are a DOD Spacelab mission, a Get-Away Special bridge support structure, and several Hitchhiker missions. The enhanced multiplexer-demultiplexer pallet, part of the Spacelab pallet system, will be verified with the TSS mission in early 1991. We work toward an FY 1991 launch of the next international Spacelab module mission, Spacelab-J, a combined Japanese/NASA life sciences and microgravity mission, and begin preliminary integration efforts on the USML-1 (United States Microgravity Laboratory) to be launched in early calendar year 1992. The 16-day EDO capability is targeted to support this flight. We continue to work with the European Space Agency, builder of the Spacelab system, for spares procurement and operation of the depot maintenance program for U.S.-provided and European-supplied hardware.

Upper Stages

The Upper Stages budget request for FY 1990 is $88.6M. The Upper Stages program is composed of Inertial Upper Stages (IUS) and Transfer Orbit Stage (TOS) procurement and a Solid Propulsion Integrity Program (SPIP). Upper stages boost payloads to orbits and trajectories not attainable by the Shuttle or ELVs alone, as demonstrated successfully on our recent STS-26 and STS-29 TDRS missions. Requested funds will procure stages and provide technical monitoring and project management. IUS vehicles are procured through the DOD.

The TOS program is a commercial venture by the Orbital Sciences Corporation (OSC), and these vehicles are procured directly from OSC. The SPIP project, initiated in 1984, establishes an engineering base for improving the success rate of U.S.-built solid stages, and we have carefully coordinated with the DOD to avoid duplication of efforts in this vital program.

In FY 1989, production of IUS will continue for the TDRS-E, -F, Galileo, and Ulysses missions. In addition to IUS, Ulysses will use a modified Payload Assist Module (PAM), a commercial upper stage produced by the McDonnell Douglas Astronautics Corporation. We will launch two IUS missions in FY 1989 aboard the Space Shuttle (TDRS-D and Magellan). The TOS upper stages for the Advanced Communications Technology Satellite (ACTS) mission and the Titan III launch of the MO mission will continue production in FY 1989. No funds have been provided beyond FY 1989 for continued procurement of a TOS for ACTS. The SPIP program will continue work on building the engineering base on solid propulsion stages in the areas of nozzles and bondlines, propellants, combustion dynamics, and verification testing.

The FY 1990 funding request will support the IUS/Galileo launch, preparation of the IUS/PAM-S/Ulysses for an FY 1991 launch, and completion and storage of IUS vehicles for the TDRS-E and -F. The TOS for the MO mission will continue production for launch in FY 1992. The SPIP will expand its investigation by examining materials, design tools, fabrication processes, and controls. It will examine product evaluation and verification methods and improve engineering practices, procedures, and communications within the nation's solid propellant community.

Engineering and Technical Base

A strong Engineering and Technical Base (ETB) is essential to the continued success of the Space Shuttle and all current manned space flight programs. It provides an absolutely critical foundation for our space efforts, including our core ability to build Space Station Freedom.

ETB provides the core capability for the engineering, scientific, and technical support at JSC in Texas; KSC in Florida; Marshall Space Flight Center (MSFC) in Alabama; and Stennis Space Center (SSC) in Mississippi. This support consists primarily of contractor manpower to operate and maintain facilities and laboratory equipment.

The ETB core varies from center to center due to programmatic and institutional differences. At JSC, ETB provides for five-day/one-shift operations in the engineering and development laboratories (such as the Electronics Systems Test Laboratory and the thermal test area), as well as at the White Sands Test Facility. ETB provides centerwide computational services and for Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) support for the OSF.

At KSC, the core level primarily provides for technical laboratory support in such areas as launch equipment testing, materials testing and malfunction analysis, robotic applications for payload preparation, and digital electronics test and evaluation as well as SRM&QA support. At MSFC, the core level provides for multiprogram support to technical laboratories and facilities and to test facility operations. ETB funds also provide for computational services at MSFC as well as SRM&QA support. At SSC, ETB funds continue SSME test support as well as the technical base supporting the ASRM program and ALS technology development.

The FY 1990 funding request of $189.8 million provides necessary capabilities at each of the OSF centers and is needed to:

- o Meet increasing SRM&QA requirements due to implementation of the Rogers Commission recommendations, processing of three orbiters in flow, and providing independent flight software assurance.
- o Continue the enhancement and development of Class VI computer capabilities used to support multiple programs.
- o Provide a minimal increase of support contractor manpower to meet requirements associated with new and enhanced facilities and laboratories.

Payload Operations and Support Equipment

Payload Operations funding of $60.4 million will furnish continued payload services for currently scheduled launches. Major NASA payloads receiving support during this fiscal year include Hubble Space Telescope, TDRS, Galileo, Ulysses, Space Radar Laboratory, Space Life Sciences Laboratory, Upper Atmospheric Research Satellite, and Gamma Ray Observatory. Provision has been made to replace outdated engines on the Super Guppy aircraft required for ferry of outsized payloads. Funding is required to assure compatibility between Shuttle capabilities and Space Station Freedom transportation requirements. Initial efforts are under way to support development of a standard orbiter docking system to be used by Space Station Freedom and other on-orbit docking requirements. The payload support equipment requirement of $20.7 million is to upgrade selected payload capabilities for safer, more efficient operations. FY 1990 funding for multimission payload support equipment is required to develop, test, and deliver Payload Common Communication Equipment (PCCE) to accommodate required payload data transmission and initial spares provisioning for cargo integration test equipment and PCCE. Funds for fiber optic cabling and an upgraded operational intercom system at KSC provide increased data transmission reliability among cargo facilities.

Advanced Programs

The Advanced Program Development request is $48.7 million in FY 1990. Studies of future space transportation and related requirements are the focus of this program area. In FY 1990, emphasis will be on advanced space transportation systems, advanced operations support systems, satellite servicing systems, and advanced missions.

In advanced space transportation, preliminary design studies begin this year for the Assured Crew Return Capability (ACRC). We will continue to study in detail vehicle concepts required to meet medical emergencies.

Conceptual studies will also be initiated this year to investigate three alternate approaches for civilian manned transportation system evolution. These studies will pursue concepts for evolution of the current Shuttle, a smaller personnel launch vehicle, and an advanced manned launch system.

We believe an unmanned heavy-lift launch capability is very much in the national interest. The Shuttle-C concept NASA has identified would provide a near-term capability to boost between 100,000 and 150,000 pounds with comparatively low cost and low risk. System definition for Shuttle-C will continue through FY 1989.

NASA is also studying options for transportation capabilities to support the Administration's policy to expand human presence beyond low Earth orbit into the solar system. Evolutionary concepts for a high performance upper stage, the Space Transfer Vehicle, will be studied to initially support unmanned planetary and geosynchronous missions and evolve as required to support human exploration. These studies support NASA's Office of Exploration.

These studies and activities will support national requirements as they are defined. We will continue to work closely with the DOD to define national needs and options to support requirements as they emerge.

We also continue to enhance the cost effectiveness, mission success, and human safety of manned flight through the improvement of operations support systems. The advanced operations effectiveness initiative begun this year emphasizes high leverage expert and autonomous systems technologies in the flight program environment. Near-term efforts focus on ground and flight operations for current systems with longer-term emphasis on improving future transportation requirements and support system operations.

Understanding of the orbital debris environment is another study area to improve in-space safety. Orbital debris studies are continuing to define the environment and its trends, assess the potential damage effects, and evaluate protection concepts. Emphasis is focused at Space Station Freedom altitude.

This past year NASA prepared and submitted the results of a comprehensive study entitled "Satellite Servicing: A NASA Report to Congress." NASA has subsequently established an On-Orbit Servicing Steering Committee to focus activities and to develop a coordinated approach. Ongoing systems studies are oriented toward enhancing on-orbit servicing utilizing Shuttle capabilities and to ensure compatibility with Space Station Freedom and OMV.

Advanced Launch System

The DOD/NASA report submitted to Congress on January 5, 1988, set forth the ALS program as a joint DOD/NASA program for which DOD has primary funding responsibility. NASA has the funding responsibility to satisfy unique civil requirements not addressed by the ALS baseline program.

In FY 1989, $96.5 million was made available to NASA from DOD to fund the NASA-directed ALS propulsion effort. Of this amount, $74.9 million went to Capability Development, $15.0 million went to Construction of Facilities, and $6.6 million went to Research and Program Management. Our ALS efforts are focused toward demonstrating the performance and operating capabilities of critical propulsion system components prior to committing to final design for the flight hardware development program. Liquid propellant engine and SRB components and subsystems are the focus of this activity. The FY 1990 funding for the Propulsion Advanced Development Program within the DOD budget request has not yet been determined.

NASA is requesting $5 million in FY 1990 to address unique civil requirements which build upon the ALS. The ALS/civil studies initiated this year are refining the definition of mission requirements and civil program requirements. Inherent is a series of tradeoffs to determine the most effective means of providing services to nonstandard spacecraft and payloads.

Tethered Satellite System

For FY 1990, $19.9 million is requested for development to conduct space experiments at distances up to 100 kilometers from the Shuttle. TSS is a joint U.S./Italian cooperative effort established in March 1984 for conducting upper atmosphere and ionosphere experiments. The U.S. is responsible for overall program management, systems engineering and integration, plus orbiter integration, ground and flight operations, development of the deployment mechanism, and non-European science instruments. Italy is responsible for satellite design and development, the European instruments, and integration of science instruments into the satellite.

In FY 1989 subsystem hardware will be completed and system qualification will begin. In FY 1990 TSS qualification will be completed, and flight hardware is scheduled for delivery to KSC. The first Tether mission is scheduled in early calendar year 1991.

Orbital Maneuvering Vehicle

The OMV request for FY 1990 is $107.0 million. A small "space tug," OMV will conduct orbital operations beyond the practical operational range of the Shuttle. Through direct man-in-the-loop control, the OMV will be able to deliver, maneuver, and retrieve satellites at altitudes as high as 1,200 nautical miles above the Space Shuttle. It will reboost satellites to their original operating altitudes, and safely deorbit satellites which have completed their missions. It will retrieve satellites, carry them to the Shuttle for repair or refuel them on Space Station Freedom, and return them to their operating orbits.

FY 1989 resources are continuing the OMV design and development. We are studying OMV compatibility with Space Station Freedom and ELV requirements.

FY 1990 funds will support the continued OMV design, development and testing, and the production of one flight unit. The OMV first flight is scheduled for November 1993.

Responses to written questions submitted by Chrm. Gore.

Advanced Solid Rocket Motor

When this Committee endorsed the ASRM concept in the FY 1988 NASA Authorization Bill (P.L. 100-147), there was a strong base of support within the Stever Commission -- the National Research Council's Panel on the Technical Redesign of the Space Shuttle Solid Rocket Booster -- for a clean sheet approach to a new advanced solid rocket motor that incorporated the most up-to-date technology and manufacturing processes.

Question 1: Admiral Truly, does the Stever Commission still endorse this program, and does it still believe a new solid rocket motor would enhance the safety and reliability of the space shuttle?

Answer 1: Yes, as their report stated, they believe there should be continued enhancements to the RSRM as well.

Question 2: What is the position of the NASA Astronaut Office concerning the use of solid motors versus liquid motors? the redesigned motor versus the advanced solid rocket motor?

Answer 2: The position of the Astronaut Office is that safety must be the primary concern in the use of any booster system for the National Space Transportation System. In principle, the use of a liquid booster could provide safety advantages over the use of a solid rocket for a variety of reasons including the ability to control or terminate the thrust and a design that does not require assembly joints. As a practical matter, we recognize that the incorporation of liquid booster rockets into the NSTS may be difficult and costly. Additionally, integration of a liquid booster system into the current NSTS has the potential to present other flight safety related problems resulting from the different interfaces which would be required. These trade-offs need to be analyzed in detail by the NSTS Program. Moreover, the Program should seriously consider whether the money spent on the development of either a liquid booster system or an ASRM would be better spent on the development of either a liquid booster system or an ASRM would be better spent on improving the productivity and quality control in the manufacture of the current booster rocket and in enhancements to crew safety in the event of a range safety action. Options include a thrust termination system and an SRB destruct package that would preserve for the crew an opportunity to utilize the crew escape system.

We all learned the hard way that the performance of the pre-51L solid rocket motor was not well understood even though our experience base at that time encompassed 57 motor firings. Our current knowledge of the performance of the Redesigned Solid Rocket Motor (RSRM) is significantly improved based on a thorough audit of the design after the Challenger accident and a new series of ground test firings conducted during the last 3 years. By the time an Advanced Solid Rocket Motor (ASRM) would be available we will have amassed a great deal of confidence in the safety and reliability of the RSRM. Depending on the magnitude of the design changes between the RSRM and the ASRM, to develop an equivalent level of confidence in the ASRM will require at least a very robust program of ground test firings.

Both the Stever Group and ASAP expressed concerns that funding the ASRM program would erode efforts to continuously upgrade the existing space shuttle system.

Question 3a: What is NASA's proposed level of funding for space shuttle anomaly resolution, product improvements and upgrade activities in the FY 1990 budget request? What was the level of funding requested by the Centers?

b: What were some of the principal improvements rejected by Headquarters, and were they rejected because of technical merit or lack of budget resources? What items are currently being considered as additions to this list?

Answer 3a: While we do not categorize the budget into anomaly resolution, product improvements and upgrades, and supporting tests, we have made a general estimate which is about one-third of the NSTS budget of $1.4 billion. Indeed, the NSTS capability development budget of $1.290 billion encompasses virtually all improvement activities (there are a few operational improvements covered in the Shuttle Operations portion of the budget as their activity is primarily related to operations).

Funding levels requested by the centers is generally higher than that approved by the Program. For FY 1990, the initial submits were about $1.9 billion for Capability Development.

There are several major improvements to Shuttle hardware and facilities which are in work, and which comprise a significant portion of the budget. They are listed in Enclosure 1. This enclosure lists these changes, the reason for the change, the estimated date of completion, and the estimated total cost. In addition, there are a large number of small changes which are incorporated in the various contracts, but the cost status of which are not discreetly tracked. These are included in Enclosure 2. In the case of the Orbiter, they are primarily return-to-flight modifications still open after October 1, 1988, for incorporation into Atlantis and Discovery.

b: The majority of improvements rejected by Headquarters affected the Orbiter project. The project requested a major modification program to upgrade the orbiter capabilities and protect against obsolescence. The proposal was rejected in the near term by budgetary reasons, although the Shuttle program has initiated a program-wide review of potential upgrades and improvements that would allow the Shuttle to support the nation's manned space flight requirements for the foreseeable future. In the interim, improvements and upgrades are only approved when there is a compelling justification, primarily for safety or to assure the flight manifest is achieved.

Since the Challenger disaster, NASA has invested nearly $2.5 billion for anomaly resolution and Rogers Commission activities. Of that amount, nearly $800 million was spent to redesign and recertify the space shuttle's solid rocket boosters.

Question 4: How safe is the redesigned solid rocket motor, and what added degree of safety and reliability is offered by the ASRM? What risks does a new motor present to space shuttle operations?

Answer 4: A successful test program of a magnitude unprecedented in the solid propulsion industry was conducted to recertify the solid rocket boosters for return to safe flight. Included were sub-scale, full scale short-duration and full scale full-duration tests. For the first time, margin testing was conducted by including artificial flaws which were more severe than could conceivably occur during manufacture and/or assembly. We have full confidence in the RSRM. The added safety and reliability of the ASRM is a reduction of Criticality I failure modes over the RSRM by about 20%, failure causes by about 25%, and failure points by about 30%. The ASRM presents no risks above those inherent risks associated with any new design.

There appears to be renewed interest in liquid rocket boosters as a result of activities in the advanced launch system.

Question 5: Did NASA do a "quick look" assessment of incorporating liquid rocket boosters into the space shuttle program? What were the results of those studies?

Answer 5: NASA conducted a phase A study of liquid rocket boosters from October, 1987 - March, 1987. The phase A results show that the liquid rocket booster concept is feasible. However, much work remains to be done with respect to integration impacts, costs, and time to operational use. Liquid rocket boosters as well as other improvements to the Shuttle remain options for future decisions in context with overall NASA requirements.

Question 6: What are the advantages and disadvantages of solid motors versus liquid motors?

Answer 6: A solid rocket motor is less complex in design and construction than a liquid engine. This is an advantage both in the manufacturing of the motor and in design and construction than a liquid engine. This is an advantage both in the manufacturing of the motor and in the inherent risk associated with a more complex system. The disadvantage of the solid rocket motor lies in the inability to terminate thrust once ignition has occurred.

Question 7: What liquid booster activities are currently under way in NASA, and what is NASA's position on incorporating liquids into the Space Shuttle?

Answer 7: We share the Panel's interest in the liquid booster system, but with the realization that liquid boosters represent a significantly increased programmatic risk, we have conducted conceptual definition studies of liquid rocket boosters for the STS including both pressure-fed and pump-fed concepts. These studies concluded that liquid rocket boosters offer the potential for enhanced risk management in terms of abort options but would require development and facility costs and a longer schedule for implementation. The technical issues and costs to integrate the liquids into the Shuttle stack would further exacerbate the cost and schedule risks. Nevertheless, the agency is continuing to look at liquids as part of a longer term STS evolution strategy.

Technical Enhancements of the Proposed ASRM

The proposed Advanced Solid Rocket Motor represents a concerted effort on the part of NASA and the winning contractor team of Lockheed/Aerojet to address the key problems still inherent in the redesigned solid rocket motor that is currently being used by NASA.

Question 8: Would you please give the Subcommittee a brief description of the major design changes that have been proposed for the space shuttle advanced solid rocket motor and what these design changes will mean to safety and performance?

Answer 8: Enhanced safety will be realized through both ASRM design and manufacturing. Several design features of the ASRM will improve the safety of the Space Shuttle:

- Field joints are designed to close rather than open when the motor is pressurized, eliminating the most likely cause of joint leakage.
- The number of factory joints is reduced through use of weldable case materials, eliminating four criticality 1 failure modes.
- The ballistic design obviates the necessity to throttle the Space Shuttle Main Engines (SSME) during the region of maximum dynamic pressure, thus eliminating or reducing approximately 175 criticality 1 and 1R modes for SSME and auxiliary power units.
- The nozzle redesign reduces the number of parts and the number of joints, eliminating about sixteen criticality 1 and 1R failure modes.
- The asbestos-bearing materials are replaced.

The ASRM will reduce criticality 1 failure modes by about 20 percent, failure causes by about 25 percent, and failure points by about 30 percent. Furthermore, the new design criteria for all joints to close upon pressurization is a positive design solution (rather than a fix), and obviates the need for the use of heaters. In addition, we are confident of a performance increase of approximately 12,000 lb payload capability.

Question 9: Besides the design changes, what benefits are there associated with construction of the new motor in a state-of-the-art manufacturing facility? Is it fair to say that the facility is as important to the reliability of the motor as the technical changes?

Answer 9: The new facility is as important to the reliability of the motor as the technical changes. To achieve the level of process control and automation which is needed for safety, high quality, and reproducibility, NASA has concluded that a new manufacturing facility is required to produce the ASRM. A modern optimized processing facility will introduce stringent process controls and automation features into nearly every operation in the production of the motor. Current motor production entails labor intensive operations that could lead to variations between motors and increase exposure to hazards. To achieve the intended level of quality and reliability, the process flow and the resultant facility must be optimized so that operations progress in an orderly manner. Cleanliness and environmental controls will be provided for critical processes.

In addition to flight safety and reliability, our planned ASRM implementation equally addressed industrial, public, and environmental safety. Automation of current labor-intensive manufacturing operations will not only add to the safety and reliability of the flight hardware but will minimize personnel exposure to hazardous operations. Use of water transportation will significantly reduce public exposure to potential transportation accidents. Also, the new plant is being designed to minimize hazardous wastes and to dispose of them more effectively to preclude environmental deterioration.

Responses to written questions submitted by Sen. Garn.

Question 1: At the time of last year's hearing, the House had proposed a $200 million cut in your request for Space Shuttle program. Frankly we got lucky, and were able to minimize the impact on operations largely through a $100 million transfer from the Department of Defense. But the overall budget situation, if anything, is even worse this year, and the possibility of additional DOD transfers far less likely. I have no doubt that if we decide to fund your $121 million request for ASRM, it very likely will have to be absorbed out of shuttle operations. Would you recommend proceeding with ASRM under these conditions?

Answer 1: Shuttle operations funds the ongoing launch of the Space Shuttle which is the agency's highest priority. The timely achievement of the planned launch rate in a safe manner is absolutely critical to the nations scientific and national security programs. NASA is not prepared to compromise the safety margins in Shuttle Operations. Development of the current budget submission required a difficult decision to delete some flights in order to issue safety margins within the requested FY 1990 Budget levels. Continued erosion of the flight rate for budgetary reasons would have a significant adverse impact in the nation's total space program.

The ASRM is needed to provide substantially improved safety margins and reliability for the Shuttle system, and to enhance and restore the payload performance which has been eroded by the redesign effort. As such, the ASRM is critical to the long-term success of the space program, and every effort will be made to preserve the program. A significant budget reduction would require schedule adjustments or possibly trade-offs within other areas of the NASA program.

Question 2: Last year we were forced to cut funding for the Space Shuttle Main Engine (SSME) production, test and improvement activity by $111 million, again largely because of overall budgetary constraints. In the budget before us, you are requesting an increase of $96 million, effectively restoring last year's cut. I have no statistics on this, but it certainly is my impression from discussions with many engineers familiar with the shuttle program that the SSME represents a substantially more serious concern than the RSRM, in terms of margins of safety and reliability in both its design and in manufacturing. What priority do you give to SSME improvements relative to that proposed in the ASRM program?

Answer 2: The SSME is and will continue to be a top priority in the Shuttle program. We are continuing an extensive ground test program to demonstrate margin, as well as looking at future improvements to the design and operation of the engines. The liquid engines are a more complex system that does entail more criticality 1/1R failure modes. However, to assure the safety of the entire orbiter system and the crew, all other criticality 1/1R failure scenarios must be given top priority as well. The ASRM will reduce or eliminate 175 criticality 1/1R failures by eliminating throttling of the SSME. Therefore, the ASRM will enhance SSME and system reliability.

Question 3: The Aerospace Safety Advisory Panel (ASAP) questioned the claim of superior safety and reliability flowing from the ASRM program. Although I hope to learn more on that in this hearing, I understand that one of the responses to this criticism is that the ASRM is also designed to yield a 12,000 pounds performance gain which justifies the effort on the basis of Space Station deployment concerns. Unfortunately, the program most at risk in this budgetary cycle is the Space Station. Although I am committed to do all I can to prevent termination of this critical program, should the program be killed, are there any other identified launch requirements which require the additional 12,000 pounds capability enhancement?

Answer 3: An industry-wide search for solid rocket motor safety enhancements following the Challenger accident was the genesis of the implementation of the Advanced Solid Rocket Motor (ASRM) program. Within the constraint of maximizing utilization of existing hardware inventories, those enhancements which were necessary and sufficient to return to safe flight with confidence were incorporated into the Redesigned Solid Rocket Motor (RSRM). The redesign, however, has by no means exhausted safety enhancements which NASA believes should be pursued for the long-term operation of the Space Shuttle. The ASRM is an excellent opportunity for making these safety enhancements. The ASRM will reduce Criticality 1 failure modes by about 20 percent; failure causes by about 25 percent; and failure points by about 30 percent. Furthermore, the new design criteria for all joints to close upon pressurization is a positive design solution and obviates the need for the use of heaters and the concern expressed in the report of the Aerospace Safety Advisory Panel relative to the necessity for a more compliant o-ring material. Notwithstanding the distinct safety enhancements for the ASRM, the reshaping of the thrust/time trace also adds measurably to the overall safety of the Shuttle by eliminating the need to throttle the Space Shuttle Main Engines during that portion of the launch when maximum dynamic pressure occurs.

In addition to flight safety and reliability, our ASRM implementation equally addresses industrial, public, and environmental safety. Automation of current labor-intensive manufacturing operations not only adds to the safety and reliability of the flight hardware but also minimizes personnel exposure to hazardous operations.

The increased performance capability provided by the ASRM remains an important consideration. We have been flying most Shuttles at maximum lift capacity and the payload demands ahead of us are even more challenging. Substantial benefits can be realized by using the ASRM, particularly for those flights related to Space Station deployment. Studies have shown that the additional performance provided by the ASRM is cost effective. The total additional lift capability provided by the ASRM will be equivalent to the payload capacity of 24 Shuttle flights over a ten-year period of operation, assuming a flight rate of 14 per year.

Question 4: Please briefly describe the proposed "private financing" of the construction of the ASRM plant. To what extent was contractor (or third party) ownership of the plant, along with lease-purchase or lease with option to purchase, considered in this procurement action?

Answer 4: Offerers were required to submit a privately financed as well as a government financed option. The privately financed arrangement, (i.e. government acquires title immediately, lease-purchase, or lease with option to purchase) was left to the discretion of the offerers. In addition, the offerers had an option to propose a privately owned plant. No private ownership options were submitted.

The proposal chosen was the private financing arrangement proposed by Lockheed. In this proposal, NASA will immediately take title to the ASRM facility. The private financing of the ASRM plant will be a variable interest loan, and the rate will be readjusted every six months. Borrowing only will occur when funds are needed. The full cost of the project will not be borrowed up front.

Question 5: I should take a moment to note that my concerns over the ASRM program are NOT motivated by a parochial concern over defending Thiokol. In fact, I understand that Thiokol is a major subcontractor in the successful bidding team and stands to gain about a quarter of the ASRM development contract value. It is unavoidable, however, to compare their activities under the existing RSRM contract with that proposed in ASRM if only because they will likely continue building motors for the next ten years regardless of our decisions on ASRM. The Thiokol plant is contractor owned, and I understand that in recognition of possible improvements and efficiencies yielded in the manufacturing process, they have proposed to invest about $150 million of their own money to upgrade their plant, and to amortize the cost of these improvements within the existing price of motors being charged the Government.

Why should the Government spend in excess of $500 million to build its own separate plant (including equipment), if there is a privately owned plant which can, and will be upgraded, at no additional cost to the taxpayers?

Answer 5: NASA and Morton Thiokol Inc., (MTI) Wasatch Division have entered discussions on modernization of the Wasatch facility. The discussion centers around the upgrade of their facility at an estimated cost of $250-300 million. Morton Thiokol Inc. would finance the improvements and recover their investment through cost savings incurred on the block 3 buy of the RSRM. This plan is in the preliminary stages and the details have not been finalized. In addition, this plan has not been presented to or approved by the Morton Board of Directors, or NASA top officials. Accordingly, in the absence of a firm commitment, the likelihood of an upgrade remains hypothetical. Although this option may prove attractive in the future, it will not provide the performance benefits projected for the ASRM. Furthermore, Congressional direction following the Challenger accident urged NASA to instill competition into the SRM program. A government facility will give NASA the latitude to change contractors, should the need arise.

Question 6: To what extent will the Congress have to provide additional legislative authority to permit NASA to enter into the proposed "private financing" contractual arrangement (in terms of termination liability).

Answer 6: NASA will need legislative authority to assume contingent liability to protect the contractor's investment in the event the ASRM program is terminated for convenience before the cost of the plant and its equipment has been amortized. This authority is needed because it is a violation of the Anti-Deficiency Act to insure even a contingent liability above the level of available appropriations. The authority to incur this contingent liability is preferable to obtaining actual appropriations to cover the liability because the long-term nature of the space program makes it highly unlikely that the contingency will occur. Thus, making funds available to fund the contingent liability would exacerbate this year's budget problems by requiring the appropriations of funds that will, in all probability never be expended. Instead, the contingent liability will be amortized by expenditure of funds appropriated for the purchase of ASRM's.

Question 7: The Aerospace Safety Advisory Panel report recommended that "NASA reexamine the plan to procure the ASRM and study other options for the replacement of the current solid rocket motors...(including) liquid rocket motors." What is the current status of NASA actions with respect to this recommendation?

Answer 7: NASA had considerable discussion of this issue prior to the Advanced Solid Rocket Motor program decision. The decision was made as a result of safety, technical, and programmatic considerations. NASA plans to continue with the ASRM. (Attached is a memo sent to Mr. Joseph F. Sutter, Chairman of the ASAP, stating NASA's position)

Shuttle-C

Question 8: As you know, I am a strong advocate of the Shuttle-C. Rather than yielding a modest increase in what individual orbiters can carry within the constraints of a small shuttle fleet, the Shuttle-C would more than double our payload capability and is not dependent on the availability and processing constraints of the orbiters. And it would more efficiently utilize existing production capability for external tanks and booster motors. Do you agree with my analysis of the merit of the Shuttle-C program?

Answer 8: If approved, Shuttle-C could deliver approximately 100-150 thousand pounds to orbit depending on whether two or three main engines are used. The Shuttle-C concept has an unmanned cargo element in place of the Shuttle orbiter, and a new processing facility would be required for this cargo element. The cargo element design allows for use of existing and planned NSTS payload processing capabilities. The Shuttle-C could use the same production capability for external tanks and booster motors as the NSTS. However, we envision flying Shuttle-C an average of only about three times per year, with an associated reduction in the number of Shuttle flights. Hence, there should be no significant difference in external tank and booster production efficiencies.

Question 9: What is the current status of Shuttle-C development work?

Answer 9: Three parallels systems definition contracts were begun in FY 1987, to define a Shuttle-Derived Vehicle configuration most appropriate to satisfy the anticipated national needs beginning in the mid-1990's. The current Shuttle-C concept was a result of these studies. These contracts have been extended through the end of FY 1989 and, along with in-house efforts, are further defining the Shuttle-C configuration. FY 1990 funds will be needed to continue the activity to mature the Shuttle-C system design in preparation for a potential new start proposal in FY 1991.

Question 10: It is very impressive to see the table displaying "safety enhancements, net reductions of criticality 1/1R" in terms of a 21 percent reduction in failure modes, a 29 percent reduction in failure causes, 52 percent for failure points and 88% for leak paths. While I am glad to see that spending a billion dollars can yield improvements in design, it is unclear to me whether this means that a percent reduction in the number of failure modes, causes, points, and leak paths equates to the same percent reduction in risk of failure. Am I correct in that simply reducing the number of failure modes does not automatically reduce the probability of a failure?

Answer 10: Reducing the number of failure modes, causes, and points should reduce the probability of a failure. While this does not equate to a one for one percent reduction, the ASRM is an excellent opportunity for making significant safety improvements. The new design criteria is for all joints to close upon pressurization. This in itself is a positive design solution rather than a fix. Notwithstanding the distinct safety enhancements for the ASRM, the reshaping of the thrust/time trace also adds measurably to the overall safety of the Shuttle.

Question 11: To what extent can the design improvements proposed for the ASRM be incorporated into the RSRM?

Answer 11: We are presently evaluating, and will continue to evaluate, suggested improvements to the RSRM and plan to pursue those which promise a significant benefit to mission safety. However, to incorporate the design improvements into the current motor would require a new case design, as well as major modifications to MTI's facility. While it may be possible to incorporate the new automated manufacturing improvements, it should be recognized that this would entail downtime of the current production facility.

Senator GORE. Let me pick up, and I really had not intended to get into this, but your statement on risk. The impossibility of eliminating risk. I could not disagree with it the way you put it, but it seemed—it seemed in need of a little exploration because you saw the study about the probability of catastrophic failure. Boy, that is really troubling. One in 78 is the median base case. Does NASA challenge those figures?

Admiral TRULY. That particular study that you are referring to was a part of our effort that is required by law for us to make an assessment to fly the Galileo mission with an RTG generator on board later this year.

Senator GORE. But it applies to the possibility of catastrophic failure for the Shuttle as it is presently designed and operating without upgrades. Correct?

Admiral TRULY. We went through a great deal of internal debate as to how to characterize to the Department of Energy those potential failure rates. We gave them a range of numbers and they were our worst case range of numbers because of the study that we were doing.

I can tell you today that I do not believe—I do believe that it is possible, with our—the aggressiveness that we have gone after safety and reliability in the Shuttle system, that we do not have—I am not sitting here telling you that I believe that we are going to have another Shuttle accident, but the risk is there. We cannot take it out.

The other problem with those numbers in my own view, and I might ask Arnie Aldrich here to comment on it as director of the program, is the fact that we have—there are things that we have put into the Shuttle system in processing, in inspections, in reviews, that do not get into the numbers. Things that are not quantifiable.

Senator GORE. Well, before he does that let me just elaborate on my understanding of these figures and this is a NASA document that I have which gives the 20th percentile probabilities, 80th percentile probabilities and the median case probabilities.

Then it looks at each of the critical components of the Shuttle and the risk of failure associated and then it mathematically collates all of those numbers to give probabilities for the total system having a catastrophic failure.

The first thing that strikes you when you look at these numbers is that the external tank (ET) the orbiter and the prelaunch are way up there—I mean, are way down there in probability but the two elements that are a couple of orders of magnitude more troubling are the boosters and the main engine.

As between the two, the main engine poses, according to your internal assessment, a bigger risk than the boosters and it seems to me that that, when we talk about efforts to mitigate risk, underscores the need for both improvements to the main engine and an advanced solid rocket motor, because you have got a 1 in 171 risk of catastrophic failure from the main engine as it is currently designed and operating, according to these figures.

Adm. TRULY. I think your point is extremely well taken and that is exactly why, when you go through carefully with a fine tooth comb through our budget you will find that we have major investments in main engine work and it is also, as you mentioned, a reason that we are frankly so interested and have been in the advanced solid rocket motor.

We will get into this later, but one of the advantages of the advanced solid rocket motor is the fact that by shaping the propellent—by propellent shapings such that the first stage can be flown differently than it is today, we avoid the necessity to throttle down the three main engines and then have to throttle them back up, and that itself not only takes failure modes out of the motor but it removes them from the main engine also.

Arnie, would you like to make any other points?

Mr. ALDRICH. Well, I would like to say in my own way that these numbers are calculated based upon very worst case statistical manipulation of the actual failure history we have had in the program—in the test program from the very beginning and many of the items that go into these equations do not have enough real statistical base behind them to allow it to all be based on engineering fact.

A lot of it is based on worst-case analysis by engineers. We wanted to do it that way. We did do it that way and done in that fashion these numbers are, in fact, the numbers that characterize the failure probabilities. However, there are some things that are not taken into account when you approach it that way.

One of the things, particularly with regard to the main engines, are the operational techniques and the systems that back up the main engines to sense failures and operationally account for them in flight, so that what in worst case would be a catastrophic failure, in actuality we have mitigations that we use that would not show up in these calculations that give us a much better probability of a successful flight, or an alternate flight profile.

Also, we have made a number of changes to the vehicle—over 400 changes—since the accident and there is no way that the benefits and the improvements can be statistically assessed and factored into these numbers. So that also is not accounted for in the way these numbers were characterized, to give you a "worst case 'assessment of what the Shuttle failure probabilities could be for the specific purpose of assessing the RTGs.

I do agree that the main engines are probably our most critical element and the one that has in the past and still does give us the highest concern, even a little more than the solid rocket motors, but we have interacted a very extensive test program during the last three years.

We have tested main engines on the ground for more starts and more seconds and minutes than ever before on the program. We have tested both redesigns and the base engine system as we have known it, in order to get the kind of basis to have confidence that the engine will perform and that the safeguards that I mentioned will perform for us.

Senator GORE. I would like you to provide for the Subcommittee, if it is at all possible, a recalculation of these risk numbers, taking into account as best you can the mitigating factors that you referred to.

At this point I would also like to insert into the record a copy of the table I referred to and a list of activities currently being pursued by NASA to upgrade and improve the existing Space Shuttle system in order to make it safer and I want to emphasize in doing so that these improvements have to be funded.

We cannot let the Congress as a whole cut the Shuttle operation's budget this year as they did last, because it makes funding—that budget is what makes funding of these safety upgrades possible and if that particular part of the budget is cut, then these safety upgrades might well be impossible.

I have got a whole bunch of other questions, but I am going to pause and come back to them and at this point recognize my colleague, the Senator from Mississippi.

[The information referred to follows:]

Reprint from Science Applications International Corporation Report on the Use of RTGs on the Space Shuttle

	Base Case (Field Joint Failure Mode Fully Corrected by Redesign)		
	20th Percentile	Median	80th Percentile
SRBs (pair)	$\frac{1}{624}$	$\frac{1}{278}$	$\frac{1}{124}$
SSME (cluster)	$\frac{1}{458}$	$\frac{1}{171}$	$\frac{1}{64}$
ET	$\frac{1}{29{,}000}$	$\frac{1}{10{,}000}$	$\frac{1}{3{,}500}$
Orbiter (1)	$\frac{1}{5{,}300}$	$\frac{1}{2{,}900}$	$\frac{1}{1{,}600}$
Prelaunch	$\frac{1}{2{,}600}$	$\frac{1}{1{,}900}$	$\frac{1}{1{,}300}$
Total System (2)	$\frac{1}{168}$	$\frac{1}{78}$	$\frac{1}{36}$
	Sensitivity Case (Field Joint Failure Mode Not Corrected)		
SRBs (pair)	$\frac{1}{251}$	$\frac{1}{109}$	$\frac{1}{48}$
Total System	$\frac{1}{102}$	$\frac{1}{50}$	$\frac{1}{24}$

(1) Powered flight Phases 0B, 1, and 2 only

(2) Includes inadvertent destruct and accidents in Phases 2 and 3 - initiated aborts

Table E-1. Probability of Catastrophic Shuttle Failure by System for the Galileo Mission

ENCLOSURE 1

MAJOR FLIGHT HARDWARE AND FACILITY CHANGES

SPACE SHUTTLE MAIN ENGINE

Alternate Turbopump Development

This is a Rocketdyne subcontract let to Pratt and Whitney to develop improved liquid oxygen and liquid hydrogen high pressure turbopumps which incorporate improved safety margins through the use of precision casting in lieu of welding and other increased structural margin components. The pumps are scheduled to make a first flight in mid-FY 1992. Current cost estimate is $329 million through runout.

External Heat Exchanger

The external heat exchanger is a safety improvement designed to remove the potential for a catastrophic failure of the SSME should the present heat exchanger mounted internally develop a leak. The external heat exchanger will first fly on OV-105 in FY 1992 and is funded out of that account. Current cost estimate for development is $28 million, with fleet implementation on flight engines an additional $35 million.

Phase II+ Powerhead Development

The Phase II+ powerhead is an improved design which will provide a better engine environment and safety margins while decreasing weight and complexity. It is scheduled for flight implementation in FY 1995. The cost for development and certification is about $534 million. The production of the Phase II powerhead is underway and the cost of implementation on flight engines is estimated to be $73 million.

Produceability

In addition, there is an ongoing produceability program desgned to improve manufacturing techniques for the main engine which result in a lower cost to manufacture each engine. Funding for this element is approximately $13 million per year.

Product Improvement

The product improvement program is designed to improve engine component margins and reliability while extending hardware life limits. This will reduce critical failure modes and hazards while improving the reuseability of engine hardware. Funding is approximately $23 million per year.

SOLID ROCKET MOTOR/SOLID ROCKET BOOSTER

Solid Rocket Motor Contamination Control

As an improvement to the manufacturing process, Thiokol is revising their contamination control procedures. This should result in impoved process flow and reduced cost. The estimate is approximately $25 million, most of which will be incurred in Fy 1989.

Advanced Solid Rocket Motor

Advanced Solid Rocket Motor development will start in FY 1989. This program will produce 12,000 lbs. more payload to orbit as well as improve safety designed in solid boosters. The current estimate for this program is $1.5 billion through Fy 1994, excluding any facilities costs.

ORBITER

General Purpose Computers

We have redesigned the general purpose computers, increasing their speed and memory capacity. This program is almost complete and will cost about $79 million through runout. Installation and checkout will be complete in FY 1991. First flight is scheduled for STS-42.

Improved Alternate Inertial Measurement Unit

This program also upgrades the orbiter inertial measurement units to improve performance, upgrade obsolete technology, and decrease logistics costs. Total cost through runout is $53 million. Fleet implementation is scheduled to be complete in FY 1991.

Improved Auxiliary Power Unit

This activity is also to improve subsystem peformance and to increase the life expectancy of turbine wheels and other mechanical components. Most of the work has been completed; and fleet implementation is scheduled to be complete in FY 1991. The total cost is approximately $34 million.

Carbon Brakes

This program is to improve the orbiter brakes and increase safety margins during mission landing. This program will be complete in FY 1990 with the delivery of the final sets of brakes to the replacement orbiter. Total cost of the program is $13 million.

14-Inch Disconnect

This is a redesign to the Orbiter/External Tank umbilical disconnect to improve safety margins and simplify the operating mechanism. The development is funded in the replacement orbiter budget, with fleet implementation in the baseline budget. The total cost is $26 million, Fleet implementation is scheduled

ORBITER (continued)

Orbiter Drag Chute

This is another safety improvement to the landing phase of the mission. The drag chute will allow the orbiter to land with increased stopping power and control. The program is in the replacement orbiter budget, with fleet production funded in the baseline budget. The total estimated cost is $30 million, The program is scheduled to be completed in mid-FY 1992.

Improved Nose Wheel Steering System

This also is a landing safety improvement, permitting the crew increased control during the roll-out after landing. Its development is also funded under the replacement orbiter program, with fleet implementation in the baseline budget. The program is scheduled to be complete in late FY 1992. The total cost is $9 million.

Solid State Star Tracker

This program is to develop a replacement star tracker for the orbiter to replace the no-longer-in-production NASA standard star tracker. This is also funded under the replacement orbiter. The total cost is $9 million, This program will be complete in FY 1992.

FACILITIES IMPROVEMENTS

CURRENTLY APPROVED FIXES OR IMPROVEMENTS FOR KSC PROJECTS

1. Launch Complex 39 Operations Support Building

This facility will provide permanent office facilities to Shuttle support personnel, enabling them to maintain the planned STS flight rate. Approximate cost, including the building's equipment, is $27.9M with scheduled completion in June 1990.

2. Launch Complex 39 Pad A Rehabilitation and Modification

Work on the facility involves upgrading of fixed service structure elevators and replacement of the payload changeout room wall panels to enhance personnel, Shuttle systems, and payload safety at the launch site. Approximate cost is $24.3M with scheduled completion in October 1989.

3. Upgrade of the Orbiter Modification and Refurbishment Facility (OMRF) to Orbiter Processing Facility 3 (OPF-3)

This upgrade provides for a third processing bay to satisfy requirements for orbiter structural inspection, checkout, and safing operations necessary to meet the planned flight rate. Approximate cost is $88.4M with scheduled completion in September 1991.

4. Mobile Launch Platform 3 (MLP-3) Activation

This project modifies the MLP-3 to look like MLP-1 and MLP-2 and incorporates post-Challenger return to flight modifications. Approximate cost is $8.8M with scheduled completion in September 1989.

5. Fiber Optics Installation between Facilities

This project, involving numerous facilities, replaces/supplements existing copper cable capability to allow for the higher data handling requirements of future missions. Approximate cost is $12.1M with construction of the system supporting the Shuttle facilities estimated for completion by FY 1991.

6. Operational Intercom System-Digital (OIS-D)

This project funds the replacement of an outdated OIS-RF (radio frequency) system with a digital system that will allow support for multiple Shuttle processing flows and reduce the system's overall maintenance requirements. Numerous KSC facilities are involved, with hardware installation in Shuttle support areas to be completed in FY 1992. The approximate system cost is $33.6M

7. Launch Processing System Upgrades (LPS)

To enhance performance of the total LPS network (located in numerous Shuttle processing/support areas) upgrades to the computer hardware are required. Phased implementation of hardware and associated software will continue into the mid-1990's. Approximate cost of the LPS upgrades is $172.2M.

8. Shuttle Processing Data Management System (SPDMS II)

This project funds computer hardware, software, documentation, and processing systems that will provide technical and management information to support increasing flight rates. System cost is approximately $47.5M, with operational readiness scheduled for early FY 1992.

9. Upgrade of a Low Power Radar Wind Profiler at KSC

The upgrade of the radar wind profiler will increase wind data resolution to samples every 150 meters from an altitude of 1.5 to 18 Km directly over the KSC area. The upgrade will also optimize system software so that a vertical profile of wind can be generated every 5 to 10 minutes. Wind and wind shear information will support dynamic load assessment for safe Shuttle launch. Approximate cost is $1.0M with scheduled completion in September 1989.

10. Airborne Field Mill (ABFM) Measurement Program at KSC

An ABFM measurement program is needed to safely revise the natural and triggered lightning launch commit criteria (LCC). Electric field data will be collected over a 12 month period using 100+ Learjet flight hours. The generated data base will be the foundation for revising weather-related LCC and determining the need for ABFM measurements to be made on the day of launch. Approximate cost is $1.4M with scheduled completion in September 1989.

11. Ground-Based Field Mill (GBFM) Upgrade Program at KSC

The GBFM network at KSC is being upgraded to improve reliability, sensor calibration routines, and maintainability. It will use state-of-the-art electronics to enhance NASA's ability to identify triggered lightning potential for launch and landings. Approximate cost is $650K with scheduled completion in September 1989.

CURRENTLY APPROVED FIXES OR IMPROVEMENTS FOR JSC PROJECTS

1. Mission Control Center (MCC) Upgrade

The upgrade replaces obsolescent computers/equipment, including the consoles in the Flight Control Rooms, and introduces performance enhancements to enable the MCC to support the planned flight rate. Approximate cost is $281.3M with scheduled completion in October 1994.

2. Shuttle Mission Simulator (SMS) Upgrade

The upgrade includes the replacement of SMS host computers, development of an ascent/entry trainer, and SMS enhancements to provide additional flight training capacity and increased flight rate capability in support of the planned flight rate. Approximate cost is $241.9M with scheduled completion in November 1994.

3. Mission Evaluation Room (MER) Upgrade

The MER Upgrade includes equipment replacement and hardware and software enhancements that are required to make the MER compatible with the upgraded MCC. Approximate cost is $4.4M with scheduled completion in FY 1993.

4. Software Development Facility/Software Production Facility SDF/SPF Upgrade

The SDF/SPF Upgrade includes host-computer replacement and hardware/software enhancements so that the SDF/SPF can be utilized to develop and produce more-reliable flight software in support of the planned flight rate. Approximate cost is $35.0M with scheduled completion in January 1994.

5. Swing Flight Control Room (FCR)

The Swing FCR will connect the computer systems in the MCC third floor secure FCR with the computer systems of the second floor FCR, enabling the third floor FCR systems to be used to support non-secure operations. This requirement is due to an increase in the number of unclassified flights. Approximate cost is $5.4M with scheduled completion in FY 1993.

6. Flight Analysis and Design System (FADS)

FADS is a planned upgrade of the present flight design system, which is used to plan each mission from launch through landing. FADS is required to improve system performance and reliability while adding safety features. Approximate cost is $46.3M with scheduled completion in FY 1994.

7. DOD Shuttle Transportation System (STS) Downmoding

This is a realignment of planning, training, and support systems from the support of DOD classified interfaces with the STS to the support of unclassified interfaces with both civil and DOD payloads. Approximate cost is $98.3M with scheduled completion in FY 1994.

8. Information Management Information Computer (IMIC)

The IMIC facility Serves as the host computer system for the Program Compliance and Assurance Status System (PCASS). This database is being developed post 51-L as part of the System Integrity Assurance Program Plan (SIAPP), recommended by the Rogers Commission. Approximate cost is $51.3M with scheduled completion in FY 1994.

9. T-38 Pacer Classic

This structural upgrade, which impacts safety, is primarily to extend the T-38 operating life. The requirements are defined by the USAF program. The NASA T-38's are integrated into the military work schedule. Approximate cost is $27.5M with scheduled completion in FY 1994

10. T-38 Dorsal Longeron

This is a Time Compliance Technical Order (TCTO) for a safety modification of the dorsal longeron. This increases the safety factor and associated structural integrity of the aircraft upper surface longeron. Approximate cost is $5.8M with scheduled completion in FY 1991.

11. T-38 Weather Radar/Avionics Upgrades

This program will add weather radar capability and upgrade the flight instrumentation displays in the T-28 aircraft fleet. The weather radar capability would allow the aircraft to detect/avoid weather risks and would increase overall flight safety. Approximate cost is $12.1M with scheduled completion in FY 1993.

12. Shuttle Training Aircraft-4 (STA-4) Purchase/MODS

This provides for the purchase and modification of a Gulfstream II Aircraft to be used as a fourth STA. This purchase was required to supplement the existing STA fleet to support training requirements associated with the increased flight rate beginning in the early 1990's. Approximate cost is $23.5M with scheduled completion in FY 1991.

13. Shuttle Carrier Aircraft II (SCA-II) - Purchase & Modification

This provides for purchase and modification of a Boeing 747 jetliner (used) for use as a backup SCA. This eliminates a potential single-point failure in the Space Shuttle Program. Approximate cost is $61.7M with scheduled completion in FY 1991.

14. Improvement of the Abort Landing site at Yundum International Airport, Banjul, The Gambia

Upgrade current facilities to provide the full capabilities of a Transoceanic Abort Landing (TAL) site. Current status is that of an Augmented Contingency Landing site. The pending upgrade, which involves increasing the available runway rollout distance, will enhance safety and relieve launch constraints by providing a weather alternate for Ben Guerir, Morocco, when Moron, Spain is unavailable due to ascent performace limitations. Anticipated improvements include construction of a safing and deservicing area.

$1.6M has been approved to support status as Augmented Contingency Landing Site. $1.9M is now pending. $3.2M is anticipated for future work.

Scheduled completion date for approved work is 9/89. Pending upgrade is targeted for completion by 1/90.

15. Upgrade of Microwave Scan Beam Landing System (MSBLS) units

Five single "stand alone" MSBLS units will be modified so that they may be linked in tandem with each other to prevent a loss of signal should the primary unit fail. Upgrade will allow automatic switching of functions to a standby unit with no significant signal loss. Approximate cost is $1.6M with scheduled completion in December 1989.

16. Shuttle Orbiter Arresting Barriers (SOAS)

The SOAS is a device designed to arrest forward progress of the Shuttle after touchdown at a landing site where there is limited runway rollout distance available. The devices are to prevent an Orbiter from overrunning the available runway as might occur in case of a brake failure. Three units have been installed at abort landing sites in Spain (two) and in The Gambia. A fourth unit is on order. Approximate cost is $2.4M with scheduled completion in April 1989.

ENCLOSURE II

MINOR FLIGHT HARDWARE CHANGES

MISCELLANEOUS SMALL CHANGES GROUPED BY PROJECT AND CATEGORY

This enclosure lists a series of relatively small changes which are in the program or which are proposed, but for which we do not track the costs explicitly once they are incorporated in the contracts. Therefore, we have been unable to provide a cost estimate for their completion. In general, however, the are less than $300 thousand each; and typically are less than $100 thousand each.

The reasons for the changes fall into three general categories:

I Safety-of-Flight
II Performance Enhancement
III Turnaround Enhancement/Servicability/Long-Term Cost Savings

The reason for each change is indicated.

HARDWARE

SRM APPROVED CHANGES FOR IMPROVED MARGIN

	STATUS
Non-threaded bolt needed to accommodate stat-o-seal on nozzle joint #5	
Allow use of high tolerance o-rings for S&A rotor shaft	STS-29
Igniter heater and power cable installation	STS-27
Replacement of EPDM with KSNA on aft segment stiffener stubs	STS-30
Adjustable vent port plugs with Nylok fastener feature; leak check port plug with Nylok fastener feature	STS-29
Venting of Joint Protection System changing position and retainer band trunnions to point away from the ET and Orbiter	STS-29
Teflon strip installation at Factory joint near EPDM edge bond to preclude tearing of EPDM during joint expansion	STS-26
Locking feature for nozzle leak check port plugs	TBD
Design and fabricate foam core system tunnel	TBD

EXTERNAL TANK FOR IMPROVED MARGIN	First tank number to incorporate change. Subsequent tanks also have change
Incorporation Plasma Arc welding	
One half dome body weld assembly	ET-44
Dome Quarter Panel to Dome One-half body weld assy	ET-47
LO2 forward ogive weld assy	ET-42
ET Dome to Chord Weld	ET-49
ET Dome Gore to Gore Weld	ET-47
LH2 Tank Fwd Dome Circumference Weld	ET-74
LH2 Tank Fwd Dome Circumference	ET-70
LO2 Tank Major Circumference Weld	ET-74
LO2 Aft Ogive	ET-74

EXTERNAL TANK FOR IMPROVED MARGIN (Cont'd)	STATUS
Elimination of Non self locking standard length thread inserts	ET-40
Incorporate Dual Spray Gun Concept & Selected Design Changes on the Intertank	ET-31
Revise Design and Installation of Cable Attach Clips on LH2 Fwd & Aft Domes	ET-23
Change of Seal Standards	ET-51
Add Rubber Dam In Forward LO2 Tank Cable Tray Segment for Aeroheating Protection	ET-22
Change Stroke Limiter from 1.1 inch to 1.5 inch in the GO2 Vent Relief Valve	ET-40
SLA deletion from LO2 Tank and MA25 S Deletion from Barry Mounts	ET-51
Additional Proof Test for LO2 Feedline BSTRA Oad to Housing Fillet Weld	ET-61
SOLID ROCKET BOOSTER ASSEMBLY FOR IMPROVED MARGIN	
Incorporation of ripstop on main parachute	STS-34
Incorporation of MSA-2	STS-29
Adaption of an improved APU turbine wheel	TBD
SPACE SHUTTLE MAIN ENGINE FOR IMPROVED MARGIN	
Modification of FASCOS to prevent erroneous engine cutoff	TBD
AR01 - Computer Software Modification	STS-29
Bearing modifications and improvements	TBD
Blade improvements	TBD
Elimination of preburner pops	TBD
Hot Gas Sensor improvement	TBD
Large Throat Main Combustion Chamber	TBD

APPROVED OR ANTICIPATED FIXES IN SPACE SHUTTLE HARDWARE OR FACILITIES

ORBITER MODS

	MODIFICATION NAME	STATUS	REASON FOR MOD
10174	RELOCATION OF CABIN AIR REVITALIZATION SYSTEM/ ATMOSPHERIC REVITALIZATION PRESSURE CONTROL SYSTEM SENSORS	STS-28	II
10455	FUEL CELL OPERATIONAL IMPROVEMENT	STS-28	II
10477	CHIN PANEL INSTALLATION FOR LI2200 TILE	STS-28	I
10570	IMPROVED OXYGEN PARTIAL PRESSURE SENSOR	STS-29	I
10572	16 MM CAMERA INSTALLATION	STS-28	I
10661	REACTION CONTROL SYSTEM PRIMARY THRUSTER	STS-28	I
10791	MAIN LANDING GEAR DOOR BOOSTER REDESIGN	STS-32	III
11014	PARTICLE IMPACT NOISE DETECTION MICROSWITCH	STS-28	I
11018	MAIN PROPULSION SYSTEM 17" DISCONNECT REDESIGN	STS-28	I
11199	REDESIGN GASEOUS OXYGEN FLOW CONTROL VALVE	STS-28	I
		HELIUM LINE	
11311	THERMAL PROTECTION SYSTEM WATERPROOFING WITH DIEMETHOL ETHOXY SILANE	STS-28	I/III
10566	ORBITER BRAKE IMPROVEMENT	STS-31	II
11567	THICK STATOR BRAKES	STS-28	I
11656	OUTBOARD WING TRAILING EDGE TIPS REDESIGN	STS-28	I/III

APPROVED OR ANTICIPATED FIXES IN SPACE SHUTTLE HARDWARE OR FACILITIES

ORBITER MODS

	MODIFICATION NAME	STATUS	REASON FOR MOD
11710	ET/ORB UMBILICAL HOLDDOWN SPACER (6 EACH)	STS-28	III
11711	MODIFY AFT ATTACH PYROTECHNIC DEBRIS CONTAINERS	STS-28	I
11748	BALANCE BRAKE PRESSURE	STS-28	I
11775	AIRSPEED MACH INDICATOR/ALTIMETER VERTICAL VELOCITY INDICATOR RELOCATE COOLING DUCT	STS-28	III
11798	APU ISOLATION VALVE REDESIGN	STS-39	III
11813	ORBITER CONTAMINATION CONTROL	STS-39	III
11817	AFT FUSELAGE WIRE AC HARNESS	STS-28	III
11846	FORWARD REACTION CONTROL SYSTEM AC MOTOR VALVE BELLOW LEAKAGE	STS-52	I
11862	EMERGENCY EGRESS SLIDE LANDING	STS-28	I
11873	MODIFY FUEL CELL WATER RELIEF	STS-28	I
11920	FLASH EVAPORATOR SYSTEM PROTECTIVE COVER	STS-28	III
11944	UMBILICAL HOLDDOWN PINCHED WIRE	STS-28	I
11961	AFT ATTACH DEBRIS CONTAINMENT	STS-28	I
11965	RADAR ALTIMETER ERRONEOUS OUTPUT	STS-28	I
11968	WATER SPRAY BOILER STEAM DUCT TEMPERATURE MEASUREMENT RANGE	STS-28	III
11969	LOSS OF PRESSURANT TO POTABLE WATER TANK	STS-28	III
11989	CLOSED CIRCUIT TV BRACKET BULKHEAD ACTION	STS-28	I
11998	AUXILIARY POWER UNIT DRAINLINE HEATER REWRAP	STS-28	I
12054	IMPROVE SSME QUICK DISCONNECT INSTALLATION	STS-28	I
12060	ORBITER DRAG CHUTE	STS-52	I/III
12119	FUEL CELL WATER PURITY SENSOR	STS-40	II
12134	ORBITER EMERGENCY EGRESS SIDE HATCH	STS-28	I
12135	GENERAL PURPOSE COMPUTER OSCILLATOR REPLACEMENT	STS-28	III
12166	BALANCE BRAKE PRESSURE	STS-28	I
12170	AUXILIARY POWER UNIT FUEL LINE TEMPERATURE TRANSDUCER RELOCATION	STS-28	I
12220	AUXILIARY POWER UNIT FUEL TEMPERATURE MONITORING SYSTEM	STS-32	I
12329	AUXILIARY POWER UNIT INADVERTANT HOT RESTART	STS-50	I
12453	ORBITER TO PAYLOAD CHANGE-OUT ROOM GROUNDING PROVISION	STS-28	III
12494	SRB RATE GYRO ASSEMBLY RECHANNELIZATION	STS-33	I
12506	WING LOAD INTRUMENTATION	STS-28	I
12518	MID FUSELAGE 6.0 LOADS/FRAME STRUTS	STS-28	I
12615	LEXAN PANEL MODIFICATION	STS-28	III

OPENING STATEMENT BY SENATOR LOTT

Senator LOTT. Thank you, Mr. Chairman and thank you, Admiral Truly, and we are very pleased to have this distinguished panel here this morning.

Mr. Chairman, I would like to begin by asking consent that a statement from my colleague from Mississippi, Senator Thad Cochran, be put in the record.

Senator GORE. Without objection.

Senator LOTT. Admiral, space transportation programs have been very much in the news in recent weeks and I congratulate you and the agency for a very successful Atlantis launch and the Magellan Space Probe. I understand that is the first planetary mission for NASA in 10 years?

Admiral TRULY. In over 10 years, yes sir.

Senator LOTT. As I understand it now, NASA only plans one more flight in 1989, but 10 flights in fiscal year 1990. Is that accurate?

Admiral TRULY. There is only one more flight in fiscal 1989. That is a DOD mission that will be flying on the Columbia this summer. It will be the first flight of the Columbia since the accident. There are, I believe, two more flights in calendar 1989. So if I remember correctly I think there are nine flights in fiscal 1990.

Senator LOTT. NASA is ready to go with nine in fiscal 1990?

Admiral TRULY. Yes. We have been building up at a steady rate and in fact had the Columbia not been in a modification and since it has not flown, we could have flown—in other words, if we had had the facilities at Cape Kennedy to have the Columbia prepared for flight with all its modifications earlier, we actually believe that we would have easily—or, not easily, but we would have had the challenge and believe we could have accomplished an additional flight in fiscal year 1989, this summer.

Until a few weeks ago we had intended to do that, but I asked the Shuttle program to make a major assessment of the work load on the people at the Cape and the facilities and how crowded it would be to do that work and still be early in the Galileo window, planetary window to Jupiter, in October and the conclusion was that we could not fly both of those flights and still make the front end of the Galileo window and so we made a hard decision, frankly, to pull one of those flights and insert it again right after Galileo.

Senator LOTT. A lot of emphasis, of course, is being placed on safety by you, by the agency, by your predecessor, I know the questions from the chairman here this morning that one of the major arguments, as I understood it, for the ASRM was safety considerations and that we needed to start with a clean sheet, I believe that was the word of NASA—"a clean sheet of paper"—rather than tinkering around with existing motors. What is your reaction to that? Is that a consideration?

Admiral TRULY. Well, I think it is important today, since you are going to be dealing quite a bit with the advanced solid rocket motor, to portray the history, in our view, of how the program came to be. Frankly, it was born in our minds as we, even during the Rogers Commission investigation and as we began to understand in great detail the operation of the solid rocket motor.

Because of the huge pieces of steel that have to be made for a solid rocket motor and because of the long lead times, we had to use our existing hardware in order to build what is now the redesigned, solid rocket motor. But as we went through that process we slowly realized that for a Shuttle system that was going to be operating for possibly out to the year 2010 or beyond, that we could do better.

We believed that we could encourage this industry in America to build an advanced solid rocket motor, as it eventually came to be known. We believed that we could achieve advancements in quality and reliability through design. In other words, design a motor that just designed out some things that we could not design out and get the Shuttle back to flying even in the three years that we had in the down time.

The second thing that happened was that there was a tremendous interest on competition. As a matter of fact, in 1986 I received—or Dr. Fletcher received a letter from the Congress signed by over 300 Members of Congress that encouraged us to go out and have a program that opened up competition in this industry. So that was the second of the reasons that the advanced solid rocket motor came to be.

Thirdly, and later, as we got into it we realized that in a new motor we could gain performance. We could achieve a better balance of the up performance as compared to the down weight landing performance of the Space Shuttle and eventually that ended up, through studies and analysis and looking at what we believed we could achieve, the present design goal of an additional 12,000 pounds per flight performance—not just for Space Station assembly, although it will help immensely there, and for Space Station operation, but on every Shuttle flight. That represents about a 17 percent increase in performance gain, if we can achieve that 12,000 pounds and I will comment on that in just a second.

That performance gain cannot only be used to just put more weight into orbit, but for example it could put the Hubbell Space Telescope at a higher altitude, or put payloads that would like to be at higher inclinations at a higher inclination. In the Space Shuttle you can use that performance in many ways.

We did communicate with the Congress and with the Administration and we ended up with this acquisition plan that was presented to the Congress that laid out how we were going to go about this full and open competition for a new motor.

We have now completed that and Mr. Lowell Zoller, here, was head of the Source Evaluation Board. We have selected a contractor team headed up by Lockheed and with congressional approval we are negotiating that contract and we do need the Congress' assistance with appropriate legislation for contingency liability. We are moving ahead in that fashion.

The only other point that I was going to make was about the performance. I mentioned that we have a design goal of 12,000 pounds. The proposal as submitted by the winning contractor has a margin over that number of over 2,000 pounds so even though, when reality hits us in the development we believe that we have a very good shot at making that performance goal.

Senator **Lott**. Admiral Truly, I do not know exactly what our schedule is going to be this morning. We are going to have a live quorum at 10:45 and so we are going to have to break up then. I do not know whether you plan to come back or not.

Senator **Gore**. Yes.

Senator **Lott**. We do have some testimony scheduled this morning from some representatives of the Aerospace Safety Advisory Panel that have raised some questions about the advanced solid rocket motor.

I would ask you two questions. One, do you want to respond at this time to questions they have raised, or to put it in an affirmative way, are you absolutely convinced that we need to go forward with the ASRM, that we need to do it now and that for both the short-term and the long-term this is to the advantage of NASA and our space transportation system?

Admiral **Truly**. Well, first of all let me say that I do think you ought to hear, and hear carefully, the point of view of the members of the Aerospace Safety Advisory Committee that are here today and I know you will do that. We have worked closely with them. They do have differences of opinion on the way that we could spend our money for improving on safety-related parts of this particular program and I encourage their view to be heard and I will still be here, so I would rather defer that until later.

But on balance—on balance between the advancements in safety and reliability and the advantage of opening this up and having conducted a competition, full and open competition and the badly needed performance gains that we would see, my answer is yes, I believe we should go forward.

Senator **Lott**. I do not want to take up too much time, Mr. Chairman. Just one more point, then.

You mentioned the contingent liability legislation. Senator Heflin of Alabama was schedule to be here this morning, but had a conflict.

He is not going to be able to testify, but he has introduced the necessary legislation on this continent termination liability, and I am cosponsoring it, and I am sure probably Senator Gore will, too.

The question is, then, is there an urgent need for this and do we need it quickly in order for Lockheed and its subcontractors to go forward?

Admiral **Truly**. Yes, we do. We need that authority from the Congress in order to conclude the contract signing. We are in negotiations, but we do need that authority to sign the contract and for us to remain on schedule and deliver the motors on the schedule that we have.

Senator **Lott**. Well, let me pursue that.

Just one point more, and expeditiously. I mean, are things going to be delayed?

I want to get a feel for just how urgent this is.

Admiral **Truly**. Lowell, could you comment on what you see as the need?

Mr. **Zoller**. Yes, sir. Senator, this is urgently needed.

We are entering into fact-finding with the contractor right now. The contractor is constrained in not being able to conclude any agreements with the private lending institution without that kind of language and, as a consequence, the contractor is precluded from finalizing any agreements with his subcontractors.

So, it is very urgently needed so that all of those things can be concluded and we can then consummate the contract.

Senator LOTT. Thank you, Mr. Chairman.

Senator GORE. Thank you.

Next for questions is Senator Pressler, but before recognizing Senator Pressler, I want to welcome the distinguished ranking Republican of the full committee, Senator Danforth. If you have any opening remarks or words of wisdom about this or any related or unrelated subjects.

Senator DANFORTH. As usual, I have no words of wisdom. I will wait my turn.

Senator GORE. Senator Pressler.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Mr. Chairman, I want to thank you for holding this hearing on the budget for NASA's Space Transportation Program. The planned program appears impressive and consistent with our resolve to maintain the preeminence of the United States in space and aeronautics. NASA's budget request reflects a sound strategy of exploring space using a mix of Space Shuttle and Expendable Launch Vehicles. Moreover, through the Advanced Solid Rocket Motor project, the program is obviously committed to improving the safety, reliability, and performance of space flight.

The recent successful launch of the Atlantis spacecraft and its deployment of the Magellan probe is a strong indication that the program is presently on the right track and we clearly wish to maintain that high level of achievement.

As we are all aware, we are in an era of budget austerity. Thus, the challenge for us here is to arrive at a budget which reflects fiscal responsibility while at the same time enables NASA to carry out its important mission in a safe and dependable manner. This is not an easy exercise but it is the one that this Subcommittee is charged with.

I thank the distinguished group of witnesses for appearing before the Subcommittee today and I look forward to hearing their testimony regarding the funding needs of the space transportation program.

What role do you see for the ELV and is the ELV industry developing as it was expected and how do U.S. industries compare with those of other nations? That is something I am particular interest in.

What steps, if any, are required to achieve comparative parity with those nations? And they have been covered a little bit in your statement.

Admiral TRULY. Well, very briefly, and then I might ask Joe Mahon, who is in charge of ELVs for NASA to add to this. Joe, if you would like—but I believe that we absolutely do need in this nation a balance between manned and unmanned space shuttle and expendable launch vehicle capabilities.

I believe we have made great strides in that balance since the Challenger accident through two routes: One, our proved Department of Defense ELV programs which NASA has stood shoulder to shoulder with them as they have made their plans, but in our instance we have—we have been very aggressive in setting out a competitive environment where we can get out ELVs through launch services.

In other words, NASA rather than building the vehicles, we will get our ELVs through the commercial launch services of the private American industry, and we have on the street today, as a matter of fact, a request for proposal for launch services in the medium class.

Joe, would you care to add anything?

Mr. MAHON. After the Challenger, we took a look at the expendable launch vehicles in the mixed fleet and divided them into two categories: Phase I, the things that we would like to do immediately and use the ELVs for those bases. These are the scientific missions which are being launched this year, in fact, in addition to the shuttle launches.

The Phase II portion that we decided on doing is to conduct commercial procurements of four classes of vehicles, the small, medium, intermediate and large class vehicles. And what we are doing there is having RFPs to the industry to provide launch services as distinguished from hardware.

What we are buying essentially is FOB on orbit, the delivery of a spacecraft to its required place in space to a commercial contractor with the commercial entrepreneurs who produce these vehicles. We have issued the smaller one, what we call our medium class RFP, because that seems to be the entry into these space activities, and there is a greater demand by the contractors for that level.

Our plan is to buy a five-year contract to exercise an option for a five-year contract with the first year a solid buy and options being exercised each of the successive years under a commercial-type contract.

Senator PRESSLER. Now, assuming that NASA gets less than full funding—and I hope that is not the case—but what modifications in the planned space transportation programs can be made? With such modifications can the objectives and missions of the space program still be accomplished?

Admiral TRULY. Senator, I believe that and my answer will not surprise you, but I believe that after the number of cuts that were taken out of the space transportation programs in the development of this budget, in order to deliver the total NASA budget to the Congress, that a reduction in space transportation would clearly immediately result in either less safety, which we refuse to back off on, or less flights and less planning for the future, not for missions that are far down in years, but missions that we are planning in 1990 and in 1991, the very missions that were the highest priority missions and were backlogged after the Challenger accident.

I believe that this budget is too tight to consider reduction in that environment.

Senator PRESSLER. In other words, it would be almost fatal to the program if we do not get full funding?

Admiral TRULY. It would mean that we cannot fly these most precious cargoes that we have already paid for and were ready to fly at the time of the Challenger accident. And, just by the very nature of their existence, they were the highest priority ones or they would not have gotten in these early years the shuttle manifest, the shuttle and ELV manifest.

Senator **Pressler**. I think that is an important point here in terms of budget planning. I know that last year the administrator was forced to announce that unless something happened, the space station would not occur or would not go forward.

I am one who has been very concerned about the morale of the engineers and the people who work there who do not get public acclaim, sort of the professional jobs. They do not get paid as much as people do in private industry, but I think part of their pay is to have a program that is going to be, that is going to happen. There is a goal and if they are constantly hearing it is about to be cancelled or if this does not come through, this program will not go forward, and it really demoralizes the professional people.

And in my visits down there on a few occasions and in some hearings I have learned that this is very damaging. And so, I do hope that people understand that unless NASA gets full funding, it will be very damaging. It will probably cost us more money in the long run in this Senator's judgment.

Let me ask you this. Your budget request calls for $1.3 billion for shuttle production and operational capabilities in order to increase and sustain a shuttle flight rate of up to 14 a year.

Do you need funding for 14 flight capability to achieve NASA objectives?

Admiral **Truly**. We believe that we absolutely do, although it has little if no effect on the fiscal year 1990 budget because the buildup to the 14 per year is well into the out years.

It turns out that there are needs, however, that are in the fiscal year 1990 budget, particularly at Cape Kennedy and facilities that will allow us to fully utilize the four orbiters that—the three that we have flying today and the fourth one that is being built.

A great example of that is buildings that we have down there called orbiter processing facilities. We now only have two of them, and we are going to be building a third one, and they are simply hangars in which the orbiters that are not flying are being turned around to be ready to fly.

But, other than that, I do not believe there is any significant funding in the fiscal year 1990 budget as to whether that out year flight rate is 14 or 13 or 15 or 12.

Senator **Pressler**. Thank you, Mr. Chairman.

I have just been handed a note that I am needed for a quorum in the Foreign Relations Committee to vote on the FSX, and so that is my excuse. I am going to disappear in about a minute.

Senator **Gore**. Noted and accepted.

Senator Danforth.

Senator **Danforth**. Admiral, I was at a conference a couple of months ago, and a person who knows much more about science than I will ever know was waxing eloquent about the NASP, the national aerospace plane. And this speaker believed that this was one of the most promising things that we had going and that we should make a maximum effort to develop the NASP and that on the development of it rode the future of American technology and so on. And he felt that it was a question of allocation of resources between space station and NASP, and he felt that therefore, we should reallocate resources and spend more on the NASP and less on the space program.

Do you have a judgment as to how effectively and how well we are doing in the NASP program, and whether it is suffering because of the space program, and how we should view it as we are going about the process of determining how we spend our money?

Admiral TRULY. Well, certainly the national aerospace plane is a hot topic these days because of the recent recommendation by Secretary Cheney at the Department of Defense to hand the program to NASA and to cut DOD funding.

However, the NASP is not a program that I am particularly personally familiar with because it is not a program of the Office of Space Flight. It is in NASA the office that does that is the Office of Aeronautics and Space Technology.

Certainly I can tell you, though, just from recent meetings that I have had in preparation for taking over as the Acting Administrator when Mr. Dale Meyers leaves is that we are actively working within NASA. What program could be or should be put together in the event that that recommendation is the final answer?

We are working and plan to work with the Department of Defense and with the National Space Council. I would, however, say that I think that the national aerospace plane and the space station are two entirely unrelated technologies, and are not—maybe we do not have enough money for an apple and an orange, but those two are really apples and oranges and are not comparable in the same—really in the same context as to what they are to achieve.

I do believe, speaking for the Office of Space Flight, I do believe very strongly in the space station and hope very much—I appreciate the difficulty that you and the Congress have in this year's deliberations, but I trust that we can keep our eye on the future and prevail and not lose that vital national program.

Senator DANFORTH. I totally agree. I mean, I am all for the space program. And, from what I know of NASP, I am all for that, too.

I am concerned that when we face the battle of the budget for real—and, again, slicing up whatever we have, we are going to have to make some very hard decisions, and I was just interested in whatever light you had to shed on how that decision should be made.

Senator GORE. Would the Senator yield briefly for a comment and a question on this?

In the budget presented to the Congress which, of course, in this area goes partly to armed services and partly to the Commerce Committee, the funding for the national aerospace plane has been 70:30, 70 percent military, 30 percent NASA.

The 70 percent of the funding for that project which was in the military budget has been completely eliminated, and the explanation for that action was that the administration expects that 70 percent to be picked up by NASA.

Not only is the 30 percent in danger with the restrictions now imposed, but you are expected officially to pick up the 70 percent that was being taken by the Pentagon. Is it likely you can find room in this budget to absorb that 70 percent?

Admiral **Truly**. No. I think there is no likelihood of that.

Senator **Gore**. So, in practical terms this is a fiction and what the administration's budget really means is they are cancelling the national aerospace plane project. I mean, that is the net result.

Admiral **Truly**. Well, if I may amplify—and, again, I believe that the Acting Administrator who is not here today has said that if the funding remaining in the NASA budget remains and even including a $100 million transfer from the DOD which was part of that proposal that, in fact, the most that could be done or that could be restructured would be a technology program.

And there are those that believe that the national aerospace plane is such an integrated technology that it might very well have to lead to actually an experimental aircraft, perhaps not a single stage to orbit, but at least at high enough hypersonic MACH numbers to demonstrate the SCRAM jet operation because you can only advance technology so much without that vehicle.

But I would like to put very clearly on the record that this is a technical issue that I have not yet dealt with, I have been on the fringes of. But it is one, I can assure you, that NASA, the DOD, and others in the administration will be struggling with.

Senator **Danforth**. I would hope so. I think it is a very important question, and you know the business of government is making choices.

I read a statement yesterday that said that we are spending far more money than any country in the world on research, and yet we are falling behind in major areas and that half of the money that we spend on research is government money. And yet, that government money is spent in a dozen or so departments of the government, and different people are making decisions isolated from one another.

And I really think that it is important for the administration to give us guidance and certainly for NASA to give us guidance on matters within the purview and jurisdiction of your agency as to the priorities that have to be set.

Clearly, if we are spending more research money than any other country in the world and not getting what we hope out of it, a better job has to be done in thinking out where we are spending that money.

We had a big meeting in this committee yesterday that got into the philosophical question of industrial policy and different people have different views on that. But, whether you have a conservative or activist view of industrial policy, the government under any administration is going to be spending huge amounts of money on research and development and new technologies.

And I think we have to be given some sense of what the tradeoffs are and what the choices are when we make those decisions.

Senator **Gore**. I appreciate the Senator yielding to me during his questioning, and I would add the further comment that I think it puts us right back into the issue raised very eloquently in my opinion by the Chairman of the full committee, Senator Hollings in his article for the Washington Post two weeks ago. Because we can no longer pretend in the subcommittee that all of these important priorities can continue without looking at the structure of the larger fiscal policy that is now driving the whole set of decisions.

The future of the American aerospace industry will be determined in significant measure by whether or not we continue to maintain the lead with the national aerospace plane project. The future of America's role in space will be determined in large part by whether or not we proceed with the space station.

But, you know, a bare bones budget has been presented this year, and you have been cut below that, and that bare bones budget next year has to include the normal evolution of the space station program which calls for an increase that is significant, not because of a new start but because it has reached that stage in its development. And with the current blueprint, there is no way that is going to happen.

So, what happened to the national or what is in the process of happening to the national aerospace plane this year could well happen to the space station next year unless—or even this year, depending upon how these debates play out.

Like Senator Danforth, I am a strong supporter of both. Let me say a word of welcome to Senator Heflin, a distinguished former Chairman of this subcommittee and consult him on our course here.

We have structured this hearing to talk about space transportation with this first panel and then to talk about more details including the ones that I think are of most interest to the Senator from Alabama in the panel immediately following.

I have a series of questions on space transportation most of which can be answered for the record, but a few of which need to be answered in this session here. We can do those and then go to the next panel, or we can go to the issue of the ASRM now if the Senator wishes to proceed. But some of the witnesses that are most relevant to that topic will be in the panel that immediately follows.

Further complicating the matter is that in five minutes we are going to have this live quorum. So, if the Senator wishes to proceed now, he may, but I wanted to recognize some of the witnesses on this topic who will be on the next panel.

Senator HEFLIN. I appreciate the invitation to be here, and I have introduced a bill pertaining to the advanced solid rocket motor which I understand is absolutely essential before we can move forward with it and that that legislation be passed.

And however it would suit the Chairman, I am amendable to his wishes.

Senator GORE. If you—and I want to welcome Senator Garn, one of the leading authorities in the country on space policy.

I would offer or make the same request of him. If the two of you can return after this live quorum, I think it might be better to get into the whole issue with this next panel and then in the five minutes to start right now, I will do the questions on space transportation and wrap this panel up quickly.

Senator GARN. Mr. Chairman, let me just thank you for the opportunity of participating with you today, and I am perfectly happy to come back.

Senator GORE. That would be great. Well, let me do these quickly and then when we break for the live quorum that will conclude this panel, and I would invite the other witnesses to join you, Admiral Truly and Mr. Aldrich, on the second panel, and Mr. Mahon and Mr. Zoller, you will be excused at that point with our thanks.

Of course, maybe we will need you available to answer some questions on the second panel from the audience, but let me just ask quickly, Admiral Truly, a safe, reliable transportation system is the most critical element of our nation's space program.

Does the fiscal year 1990 budget request in any way adversely affect the safety and reliability of the NASA space transportation system?

Admiral TRULY. No. I think I can say confidently that we have absolutely drawn the line as the budgets were cut prior to presentation to this Congress, and we believe that we have invested in the right investments in the fiscal year 1990 budget for the operation of our flights and that the flight—if the flight rate and the workload gets too high as we demonstrate it for this summer's flight, we will back off before we push too hard.

Senator GORE. Does it affect the planned test program for systems improvements? Does the budget request adversely affect the planned test program or systems improvements?

Mr. ALDRICH. Mr. Chairman, I believe that the 1990 budget well supports the continuation of the test programs and the improvements that are mostly complete from return to flight, but then lead to evolutionary changes downstream.

Senator GORE. Does the budget request give NASA the resources required to meet the projected flight rate in fiscal year 1990 and fiscal year 1991?

Admiral TRULY. I believe that it does, but let me tell you that because of—there is a threat there, and two good examples of that threat is the loss of the plant in Nevada and also the situation where we had a shutdown of the Avtex plant out here in Virginia that makes aerospace rayon.

We have taken actions, two different actions, because they are very different situations. But those have cast—those have caused fiscal problems in the execution of the 1990 budget that we are dealing with now, and it is going to be an internal NASA problem, I believe, to resort to that.

And so I think the answer to the question would be yes, it is adequate, but the threats are very real.

Senator GORE. Does the request include prudent and adequate reserves to meet other unexpected problems of that kind?

Admiral TRULY. As head of the Office of Space Flight, I am going to hand myself a problem when I get over to be the Administrator because I believe because of the Ammoniumperchlorate and the Avtex rayon problems that we probably will need some internal NASA adjustments.

However, I want to represent to you and very truthfully that I think the 1990 budget does properly support us, but the threats are very real, and I would like to have more margin.

Senator GORE. Well, are cost overruns today in the base program reducing the level of improvements being made in the booster' engines, et cetera?

Admiral TRULY. Arnie might care to address that. That has been a problem.

Mr. **Aldrich**. I believe our improvements are being well thought through and carried forward. Some of the additional costs we have incurred have eaten into the margin that we were just discussing, but I do not believe they are eating into the right evolutionary changes that we need to make as we go forward from here.

Senator **Gore**. What steps has NASA and DOD taken to assess the fragility of the nation's space transport system and to ensure the availability of critical components? And here I want to focus briefly on the subcontractors many tiers removed from the prime contractors, problems recently highlighted by the incidents you mentioned.

Admiral **Truly**. We certainly have had these two incidents show us that we do have a fragile system in some regards.

And we are working closely, not only with the Department of Defense, but at a national level with the National Security Council in making an assessment of our threats caused by either single sources or limited sources, either at the contractor subcontractor level.

Senator **Gore**. Well, do you have any efforts to second source rayon?

Admiral **Truly**. We have looked at that. We have not decided. We are presently stockpiling rayon from the existing Avtex plant.

We are doing studies and are working with another company that has the promise of being a second source. That decision has not been made at this time.

Senator **Gore**. I want to encourage you to look even more carefully at that and also I would like to ask you to consider a formal report assessing the fragility of these components, critical components, and I would like that report, if you can do it, to look at how many of these components are manufactured by only one U.S. company, how many are dependent upon foreign manufacturers for components of the space shuttle.

Now, the ASRM financing plan—and I think that is the start of the live quorum, and I am going to wrap this up quickly and then we will proceed as I mentioned earlier. In an effort to get a handle on the estimated cost of this financing plan that I referred to earlier, the subcommittee requested that NASA do a cost analysis of three elements of the proposal using the current interest and discount rates of 10 percent and 9.1 percent, respectively.

We wanted the estimates in particular of one, the net present value of the total project, two, the net present value of the facility privately financed versus government financed, and, three, the net present value of the facility and the capital equipment privately financed and government financed. Do you have those numbers today?

Admiral **Truly**. Could I ask Mr. Zoller to respond?

Mr. **Zoller**. Yes, sir. We have part of those as far as the 9.1 percent, and it increases both the net present value of the government-funded program, and the privately financed program by about $15 million. But the differential between the two remains the same. We would find that to be true if we changed the interest rate or the discount rate.

I do not believe that it is going to change the relationship, and we can provide for the record the specific data.

Senator **Gore**. If you would provide that for us so that when we come back, we will have that to work with.

[The information follows:]

ACQUISITION COST ESTIMATES
AND FUNDING APPROACHES
FOR THE
ADVANCED SOLID ROCKET MOTOR (ASRM) PROGRAM

May 1989

ML 862 / • May 17, 1989 1:36 PM

SUMMARY

THE ANALYSIS CONDUCTED DURING THE SOURCE SELECTION PROCESS OF ASRM PROGRAM COSTS PROVIDES INSIGHT INTO ACQUISITION COST ESTIMATES AND THE RELATIVE MERITS OF ALTERNATIVE FUNDING APPROACHES.

- SINCE GOVERNMENT FUNDING IS NOT VIABLE WITHIN BUDGET FIGURES (NO C OF F IN FY 90 AND SUBSEQUENT YEARS), ADDITIONAL FUNDING FOR FACILITIES MUST BE SECURED.
- THIS ADDITIONAL FUNDING MAY BE OBTAINED THROUGH NASA BUDGET REALLOCATIONS, THE TREASURY (BONDS), OR PRIVATE BANK FINANCING.
- ASSUMING NO COST OF GOVERNMENT DIRECT FINANCING, PRIVATE BANK FINANCING COSTS $130 TO $190 MILLION MORE THAN GOVERNMENT FUNDING IN COMPARING THEN-YEAR DOLLAR OUTLAYS.
- ASSUMING GOVERNMENT'S COST OF BORROWING PRINCIPAL ONLY, THE PRIVATE FINANCING IS LESS COSTLY
- WHEN THE GOVERNMENT'S COST OF BORROWING IS TAKEN INTO ACCOUNT, THERE IS NO DISTINCT ADVANTAGE IN THEN-YEAR DOLLARS FOR EITHER GOVERNMENT FUNDING OR PRIVATE FINANCING.
- HOWEVER, PRIVATE FINANCING OFFERS NEAR-TERM BUDGET RELIEF THROUGH COST DEFERRAL, HAS REASONABLE FINANCING COST, AND HAS A NET PRESENT VALUE (NPV) EQUAL TO OR LESS THAN GOVERNMENT FUNDING.
- RESTRUCTURING THE ASRM PROGRAM WITHIN FUNDING CONSTRAINTS ADDS SUBSTANTIALLY TO THE PROGRAM COST
- REGARDLESS OF FUNDING METHOD, NASA TAKES TITLE IMMEDIATELY (GOCO FACILITY(AND HAS FULL PROVISION TO RECOMPETE THE CONTRACT IF THE PRIME CONTRACTOR FAILS TO PERFORM.

ASRM ACQUISITION PLAN

For illustrative purposes, the data used in these analyses are predicated upon the estimated costs in the Space Shuttle Advanced Solid Rocket Motor Acquisition Plan (March 31, 1989) rather than proposal data.

- The basis for this analysis is that the acquisition cost of the ASRM program is approximately $2,500 million through FY 1995.
  - Of this, about $1,000 million is for Design, Development, Test, and Evaluation (DDT&E), of which $230 million is for R&D Equipment
  - $300M is for Facilities (C of F)
  - $1,200M is for production of all flight articles through FY 95
- These data are not intended for budgetary purposes.

The portion which is analyzed for alternative financing is $530 million ($230 million for equipment plus $300 million for facilities).

TYPICAL FUNDING REQUIREMENTS

The current budget authority does not meet the requirements of the ASRM acquisition plan.

REAL YEAR DOLLARS IN MILLIONS

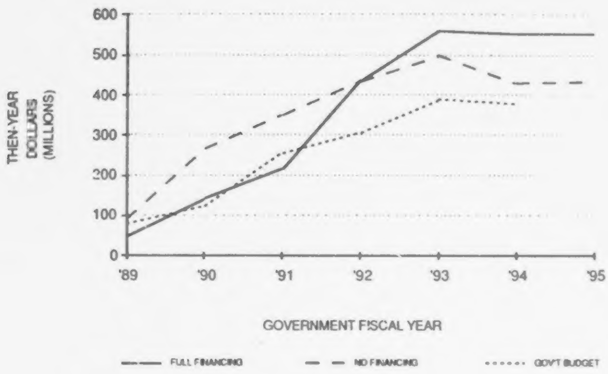
	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	TOTAL
ACQUISITION PLAN								
GOVERNMENT FUNDING								
DEVELOPMENT (R&D)	~60	195	260	250	180	50	--	~1,000
PRODUCTION (R&D)	---	---	20	115	250	380	435	~1,200
CONSTRUCTION (C OF F)	~30	70	70	70	70			~ 300
TOTAL	90	265	350	435	500	430	435	~2,500
PRIVATE FINANCING (R&D)								
TOTAL	~50	145	220	440	565	555	555	~2,530
BUDGET GUIDELINES								
R&D	51	122	254	308	392	381	---	1,508
C OF F	27							27
TOTAL	78	122	254	308	392	381	---	1,535

Through FY 1994, these figures show that the budget falls short of the Acquisition Plan by $530 million.

TYPICAL FUNDING REQUIREMENTS (continued)

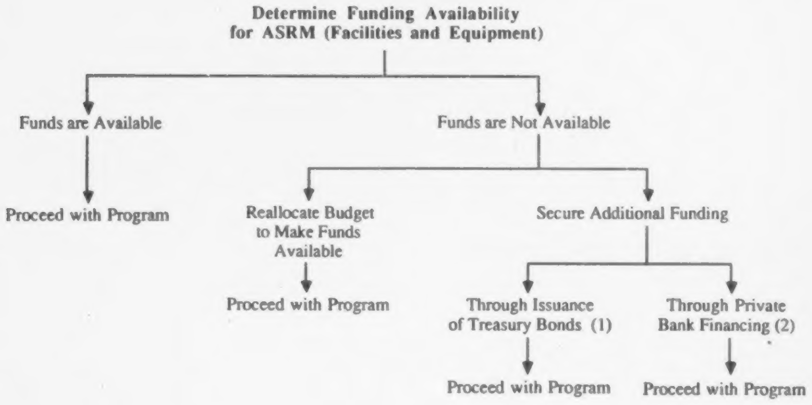
As shown, budget authority approximates the private financing outlays in the early years of the ASRM program.

ANNUAL NASA FUNDING REQUIREMENTS
ASRM ACQUISITION PLAN BUDGET ESTIMATE



FUNDING ALTERNATIVES

The determination of ASRM program cost to the Government is determined by the availability and source of funding as determined by the decision tree shown below.


Determine Funding Availability for ASRM (Facilities and Equipment)
Funds are Available
Funds are Not Available
Proceed with Program
Reallocate Budget to Make Funds Available
Secure Additional Funding
Proceed with Program
Through Issuance of Treasury Bonds (1)
Through Private Bank Financing (2)
Proceed with Program
Proceed with Program

NOTES:

(1) Interest rate determined by yield on Treasury bonds with maturity equal to loan term

(2) Cost of private financing contingent on interest rate and loan terms and conditions.

COST OF FINANCING

Whereas the Government funding option requires heavier payments up-front, the private financing option permits deferral of facilities costs to later years.

FACILITES EXPENDITURES
REAL-YEAR DOLLARS IN MILLIONS

	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	TOTAL
GOVERNMENT FUNDING FACILITY	45	130	155	130	70				530
PRIVATE FINANCING (TYPICAL) FACILITY	5	10	25	135	135	125	120	110	665

- The Government funding figures do not include any interest cost for borrowing.
- Private financing is expected to require a financing cost of $130 to $190 million in real-year dollars (variable interest rate loan)

EFFECT OF INTEREST RATES

The amount of privately financed interest is dependent on interest rate fluctuations and the terms and conditions of the loan agreement.

The table below shows how the total ASRM program interest cost changes as interest rates change from 8 to 16 percent over the total term of the financing.

Sensitivity to Interest Rate Fluctuations

Interest Rate	Total Interest	Principal	Total
8.0%	$127	$527	$654
8.6	137	527	664
9.0	143	527	670
10.0	159	527	686
11.0	175	527	702
12.0	191	527	718
13.0	207	527	734
14.0	223	527	750
15.0	238	527	765
16.0	254	527	781

Interest cost for the total program increases approximately $15 to $16 million for every one percent increase in interest rate.

EFFECT OF GOVERNMENT BORROWING
(PRINCIPAL)

When the Government's cost of borrowing principal only is taken into account, the total Government outlay under both Government funding exceeds private financing.

TOTAL GOVERNMENT OUTLAYS
($MILLIONS)

	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	TOTAL
GOVERNMENT FINANCING (I = 9.1%)									
GOVERNMENT OUTLAYS									
• FACILITIES EXPENDITURES	45	128	158	128	68	-	-	-	527
• BOND INTEREST	1	10	23	36	46	48	48	48	260
TOTAL FY OUTLAYS	46	138	181	164	114	48	48	48	787
CUMULATIVE GOV'T OUTLAYS	46	184	365	529	643	691	739	787	-
PRIVATE FINANCING (I = 10.0%)									
GOVERNMENT OUTLAYS									
• PRINCIPAL + INTEREST	1	11	25	141	140	133	123	112	686
TOTAL FY OUTLAYS	1	11	25	141	140	133	123	112	686
CUMULATIVE GOV'T OUTLAYS	1	12	37	178	318	451	574	686	-

[illegible] May 17, 1989 [illegible]

EFFECT OF GOVERNMENT BORROWING
(EXAMPLE)

- TREASURY POINT OF VIEW
  - $527 MILLION BORROWED
  - INCLUDES INTEREST ON GOVERNMENT PAYMENTS ALSO
- GOVERNMENT DIRECT BORROWING BY TREASURY AT 9.1%
  - "PRINCIPAL" IS NOT DEFERRABLE
- PRIVATE FINANCING INTEREST RATE AT 10.0%
  - PRINCIPAL IS DEFERRABLE (2.5 YEARS)
  - PRINCIPAL IS REPAID BY END OF FY 1996 (DEFINES TERM FOR BASIS OF COMPARISON)
- INTEREST COMPUTED QUARTERLY

EFFECT OF GOVERNMENT BORROWING
(PRINCIPAL PLUS PAYMENTS)

When the Government's cost of borrowing is taken into account, the total Government outlay under both Government funding and private financing is the same.

TOTAL GOVERNMENT OUTLAYS (EXAMPLE)
($MILLIONS)

	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	TOTAL
GOVERNMENT FINANCING (I = 9.1%)									
GOVERNMENT OUTLAYS									
• FACILITIES EXPENDITURES	45	128	158	128	68	-	-	-	527
• INTEREST, GOV'T DEBT	1	10	25	40	54	60	65	69	324
TOTAL FY OUTLAYS	46	138	183	168	122	60	65	69	851
CUMULATIVE GOV'T OUTLAYS	46	184	367	535	657	718	782	851	-
PRIVATE FINANCING (I = 10.0%)									
GOVERNMENT OUTLAYS									
• PRINCIPAL + INTEREST	1.0	11.0	25	141	140	133	123	112	686
• INTEREST, GOV'T DEBT	.01	.38	2	8	21	34	45	56	166
TOTAL FY OUTLAYS	1	11.4	27	149	161	167	168	168	852
CUMULATIVE GOV'T OUTLAYS	1	12	39	189	350	517	684	852	-

* *Includes a cost for Government borrowings (Government financing case) and imputed interest on Government debt (both cases)*

NET PRESENT VALUE (NPV) ANALYSIS

The cost to the Government of direct financing versus private financing of facilities and equipment for the ASRM program may also be compared using net present value (NPV) analysis.

- **NPV is an indicator of the relative merit of one option versus another. The NPV analysis technique is commonly adopted by GAO and OMB and used widely in industry.**

- **NPV analysis takes into account the time value of money which means simply that a dollar invested today at a certain interest rate is worth more than a dollar in the future. This can be represented by:**

$$FV = PV\,(1 + i)^n$$

Where:
PV = Present Value
FV = Future Value
i = Interest (Discount) Rate
n = Number of Years

- **Conversely, a dollar in the future is the equivalent of less than a dollar today. Future dollars must therefore be "discounted" back to today's terms to yield an equivalent amount in today's dollars -- i.e. the present value. This can be shown as a slightly different version of the same equation as:**

$$PV = FV\,/\,(1 + i)^n$$

- **If future dollars are discounted back to present values and added together, the NPV of the project can be determined.**

- **To the Government, the project with the lowest NPV cost is the most desirable.**

NPV ANALYSIS (continued)

The net present values of ASRM facilities and equipment financing alternatives are dependent upon the assumptions used to construct the cash flow streams.

- BOTH GOVERNMENT DIRECT AND PRIVATE BANK FINANCING ASSUME THE SAME HYPOTHETICAL DRAWDOWN SCHEDULES.

EXAMPLE DRAWDOWN ($ MILLIONS)

	FY 89	FY 90	FY 91	FY 92	FY 93	TOTAL
R & D EQUIPMENT	18	60	90	60	-	$228
C OF F FACILITIES	27	68	68	68	68	299
	45	128	158	128	68	$527

- UNDER GOVERNMENT DIRECT FINANCING, THE COST TO THE GOVERNMENT INCLUDES
  - THE $527 MILLION FROM THE TREASURY
  - TREASURY BOND INTEREST ON THIS $527 MILLION BORROWING (NON-DEFERRABLE)
  - RANGE OF INTEREST RATES 0% TO 9.1%
- UNDER THE PRIVATE BANK FINANCING OPTION, THE COST TO THE GOVERNMENT INCLUDES
  - REPAYMENT OF $527 MILLION PRINCIPAL (DEFERRABLE)
  - INTEREST ON THE UNPAID PRINCIPAL BALANCE.
  - RANGE OF INTEREST RATES 8.6% TO 10%
- RANGE OF DISCOUNT RATE 9.1% TO 11%

OVER A WIDE VARIETY OF ANALYTICAL CONSIDERATIONS, COMPARISON OF NET PRESENT VALUES INDICATES THAT PRIVATE FINANCING IS EQUAL OR PREFERABLE TO GOVERNMENT FINANCING OF ASRM FACILITIES AND EQUIPMENT.

	FUNDS FOR ASRM (EXAMPLE)			
	GOVERNMENT DIRECT FINANCING		PRIVATE BANK FINANCING	
	BUDGET i = 0%	BONDS i-9.1% T-BOND	i = 8.6% ORIGINAL	i = 10.0% CURRENT RATE
LIFE CYCLE COSTS (THROUGH GFY 2020)				
THEN-YEAR DOLLARS (M)	28,423	28,683	28,560	28,582
d = 9.1% (a-104, CURRENT)	6,196	6,357	6,197	6,212
d = 10.0% (A-104, FALL '88)	5,526	5,680	5,517	5,534
d = 11.0% (A-70, CURRENT)	4,899	4,945	4,883	4,897
FACILITY FINANCING ONLY (THROUGH GFY 1996)				
THEN-YEAR DOLLARS (M)	527	787	664	686
d-9.1% (A-104, CURRENT)	405	566	406	421
d = 10.0% (A-104, FALL '88)	395	549	386	403
d = 11.0% (A-70, CURRENT)	385	531	369	383

- INTEREST ON PRINCIPAL ONLY
- THE COST OF GOVERNMENT DIRECT FINANCING IS LESS ONLY WHEN IT IS ASSUMED THERE IS NO COST TO THE GOVERNMENT FOR MONEY OBTAINED FROM THE BUDGET.
- HOWEVER, AS STATED IN THE GAO PROJECT MANUAL, INTEREST IS A COST RELATED TO ALL GOVERNMENT EXPENDITURES AND MUST BE CONSIDERED IN SUCH AN ANALYSIS.

EFFECT OF PROGRAM RESTRUCTURING

Restructuring ASRM program within funding constraints adds substantially to the program cost.

- **Restructuring within the budget constraints results in a schedule slip and added costs due to:**
    - **Added escalation due to deferred expenditures**
    - **Added cost of ASRM program extension**
    - **Added cost of RSRM program extension (compensation for delayed ASRM introduction)**
    - **Added cost differential between RSRM and ASRM hardware**
    - **Added STS missions (compensation for lost ASRM payload capability).**
- **Cost of private financing to retain a well paced program is far exceeded by cost of restructuring within budget constraints.**

Senator GORE. Now, before we agree to a private financing scheme, I would like to know what OMB's position is. Have you reviewed this proposal with OMB?

Admiral TRULY. Yes, we have.

Senator GORE. And have they analyzed it?

Admiral TRULY. Yes, I believe that. I believe that this proposal as presented has the support of NASA and OMB.

Senator GORE. On what basis did they assess it? As a circular A–104 dealing with leases and service agreements or a circular A–70 dealing with loan guarantees?

Mr. ZOLLER. Circular A–104. This is not a lease or service arrangement, so the A–70, to the best of my knowledge, does not apply.

Senator GORE. Have we got those backwards or do you have those backwards? My understanding here is that the A-104 is the one that deals with lease and service agreements.

Mr. ZOLLER. I believe that is backwards.

Senator GORE. What, the way we have it?

Mr. ZOLLER. Yes.

Senator GORE. Then we have it right. It's an A–104 assessment.

Now, if one had to describe the proposal, you would not say it is a government owned-company operated (GOCO) or a company owned-company operated (COCO) in the traditional sense?

Mr. ZOLLER. It is, in fact, a privately financed GOCO facility. The government will take title immediately upon the expenditure of funds.

Senator GORE. Should this be described as a one-time initiative? We are not going to see OMB come back at us next year with private financing of NASA, are we?

Admiral TRULY. I trust not.

Senator GORE. What is the assumed payment stream for the Lockheed proposal in terms of federal spending for this portion of the program?

Mr. Zoller. Senator, that information is still sensitive in that we are in this very detailed negotiation with the contractor.

Basically, let me say that the principal payments are deferred about three years and then paid in equal installments. You start paying back the interest immediately. The net effect is you have a very small initial payment and then the payments increase with time.

Senator Gore. Are additional fiscal year 1990 funds required to implement this program?

Mr. Zoller. We believe that they can be accomplished within the program as outlined. Our expectation is that there could be a several-month schedule impact associated with doing that.

Senator Gore. Okay.

Now, does the Lockheed proposal assume any tax advantages or tax benefits?

Mr. Zoller. No, it does not.

Senator Gore. Pursuant to the Lockheed proposal, when does the federal government take title to the facility?

Mr. Zoller. Immediately upon the purchase of the equipment or the acquisition of materials for the building.

Senator Gore. What provisions are there in the proposal to permit NASA to substitute another contractor if the Lockheed/Aerojet team fails to perform?

Mr. Zoller. A year ago we worked with you in the preparation of the acquisition plan for ASRM. One of the fundamental provisions of that was that we had the ability to recompute the contract at any time. Those provisions have been carried forth into the RFP and into the contract negotiations, so we have that full capability at any time.

Senator Gore. Besides the ASRM facilities, what additional capital equipment is included in the proposed financing plan?

Mr. Zoller. In additional to the actual construction of the facility, we have included the plant equipment; that is, the general off-the-shelf type of equipment necessary to implement the plant.

Senator Gore. Are all of these facilities adequately covered by the language in the S. 663 or should it be amended to include major capital equipment?

Mr. Zoller. Our legal interpretation is that the term "facility" can be broad enough to incorporate the plant equipment if the Congress would chose to add those words in. It would be a clarification, and it would not detract from it.

Senator Gore. Okay. When we come back, we will start with the second panel, and then we will take it from there and I will recognize Senator Heflin for questions first. Thank you, and we will come back as soon as this live quorum is over with.

[Recess.]

Senator Gore. We will come back to order.

I know our witnesses understand what has happened, but I want you all to know, and particularly you, Admiral Truly, that we are acutely aware of the opportunity cost associated with your lengthy appearance here because you need to be over there doing other tasks.

The Constitution intervened in requiring all of the Senators to be present for the presentation of articles of impeachment by managers on the part of the House, and it was for that reason that we have had this lengthy delay.

On our second panel now beginning we have besides Admiral Truly and Mr. Aldrich, Mr. J. R. Thompson, Director of the Marshall Space Flight Center, also soon to have new responsibilities, and we are delighted to have you here, as I mentioned earlier.

Mr. George Rodney, who is Associate Administrator of NASA for Safety, Reliability, Maintainability and Quality Assurance. Welcome to you.

Mr. Charles Donlan, who is a member of the NASA Aerospace Safety Advisory Board, and Mr. Sy Himmel of the NASA Aerospace Safety Advisory Board. Welcome to all of you.

I am advised that only Mr. Himmel and Mr. Donlan have a prepared statement, and then we will ask the NASA witnesses to comment briefly, and then we will open it up to questions.

Without objection, your entire prepared statements will be put into the record, and you are invited to proceed with summaries thereof as you see fit.

And we will start with you, Mr. Donlan. Welcome.

Senator GORE. Mr. Himmel?

Mr. HIMMEL. Well, there has always been a competition between liquid and solid propellants for rockets and it did stabilize out that—at least in my view the consensus was that the solid propellant had greatest application in the military for quick response, no servicing needed to get it to launch, and that the liquid propellants with their higher performance potential were better suited to space flight for civilian purposes. Certainly, there is no sharp line of demarcation, because certain of our liquid-propelled launch vehicles of course use strap-on solid rockets. So you have a blending of the two.

Senator GORE. Well, I cannot resist interjecting at that point and asking, because this is really a critical point, and I would like to ask either Mr. Thompson or Admiral Truly to respond to this particular point.

STATEMENT OF CHARLES J. DONLAN, AEROSPACE SAFETY ADVISORY PANEL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY SEYMOUR C. HIMMEL, AEROSPACE SAFETY ADVISORY PANEL; ADM. RICHARD H. TRULY, ASSOCIATE ADMINISTRATOR FOR THE OFFICE OF SPACE FLIGHT; JAMES R. THOMPSON, DIRECTOR, GEORGE C. MARSHALL SPACE FLIGHT CENTER, MARSHALL SPACE FLIGHT CENTER, ALABAMA; GEORGE A. RODNEY, ASSOCIATE ADMINISTRATOR FOR SAFETY, RELIABILITY, MAINTAINABILITY, AND QUALITY ASSURANCE

Mr. DONLAN. Thank you, Mr. Chairman. It is a pleasure for us to be here and take advantage of this opportunity to present our views.

I would like to mention that in the course of this year we have spent most of our time, of course, covering the space shuttle effort, getting back into flying condition and the space programs. And we have been very satisfied with the progress we have seen and the improvements in the management attention to safety that has occurred here.

Our report contains a number of recommendations for enhancing the safety of the system which we will not go into here, but which are outlined in detail in the report.

I would like to cover another area of significant interest here, particularly in this panel, and that has to do with the STS solid rocket motor and the proposal to develop the advanced solid rocket motor.

The views of the ASAP on this subject have been more widely discussed than any other of our recommendations and findings. And despite the fact that it might be anticlimactic in the view of the events that have taken place, I would like to restate our views in this matter.

NASA has received very favorable reviews from some sources regarding the modifications made to the solid rocket motor. The modifications have been extensive enough so that it is now called the redesigned solid rocket motor.

Its performance in the few flights that have been conducted so far has been excellent instrument data and post evaluation have not revealed any problems that would be cause for concern.

Nevertheless there are additional enhancements and modifications in the interest of safety that can be made, and these are outlined in our report. Even so, the redesigned solid rocket motor in its present form is considered by NASA to be safe and reliable enough in its present form to fly at least for five more years. It will see well over 100 uses before the introduction of the proposed SRM and will continue to be used during a three-year phasing in period during which time both type of rockets will be used.

NASA maintains the ASRM will benefit from advances in solid rocket technology and automated manufacturing methods and hence will result in a safer and more reliable booster than the current RSRM, even allowing for the incorporation of the additional safety features I previously alluded to.

Also, it is not evident to us why some of these anticipated improvements cannot be introduced into the current production process.

In any case, from a safety and reliability standpoint alone, the ASAP sincerely questions these claims and has suggested that NASA reconsider its course of action.

NASA states that the improved performance expected from the ASRM is badly need for the Space Station Freedom program and arguably might be justified for that reason alone.

Now, performance assessment is not a prime task in the charter of the ASAP, but suffice it to say nevertheless that significantly greater performance could be obtained with liquid rocket boosters in lieu of the solids as shown by NASA's own studies and without operating the SSMEs at excessive power levels.

The significantly superior performance obtained with liquids would also allow the incorporation of safety and reliability-oriented orbiter modifications which while still satisfying payload requirements can make a safer system.

These NASA studies have also shown that the use of liquid boosters can greatly enhance the safety of aborted flights by eliminating, for example, the spectre of a ditching emergency landing.

NASA has not undertaken the studies of liquid boosters with the same zeal and enthusiasm it applied to the solids, and this is somewhat surprising in view of the shift in emphasis away from solids toward liquids in both the domestic and international launch vehicle fields.

Witness, for example, the advanced launch system studies in this country and the Japanese and European plans for manned flight, not to mention the Russian program which launches a shuttle very similar to our own.

Mr. Joseph Sutter, who regrets that he could not be here—he happens to be in England—is chairman of this committee and a noted airplane designer, asked me to state his view in this way: "NASA's determination to proceed with the advanced solid rocket motor is like a major airline staying with reciprocating power engines when the rest of the world has gone to jets."

Mr. Sutter believes strongly that NASA should reconsider its decision to proceed with the ASRM and has written to the National Research Council, which assisted in the redesign of the current RSRM suggesting that it offer its advice to NASA on this matter.

He has received a reply from Mr. Wyatt, President of the National Society of Engineering Council for the National Academy, who said they would be glad to do this if NASA requested them to do so.

[The statement follows:]

STATEMENT OF
THE AEROSPACE SAFETY ADVISORY PANEL
PRESENTED BY MR. CHARLES J. DONLAN AND DR. SEYMOUR C. HIMMEL
before the
Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

The Aerospace Safety Advisory Panel presented its annual report to the NASA Administrator and his senior managers during the Panel's statutory annual meeting on March 28, 1989, at NASA Headquarters. This report covered the Panel's activities from February 1988 through January 1989. Throughout this past year, the Panel has provided oral and written communications directly to appropriate personnel to maintain a timely and orderly feedback or closed-loop communication regarding our assessments and reactions to day-to-day operations.

The main focus of the Aerospace Safety Advisory Panel during this past year has been monitoring and advising NASA and its contractors on the Space Shuttle recovery program or safe-return-to-flight. In addition, we have strengthened our examination of the Space Station Freedom Program and have laid out a series of reviews for our 1989 factfinding efforts. We are also continuing our activities associated with NASA's aeronautics projects and aircraft operations management. Here our efforts, of course, are oriented toward improved flight safety. During this past year the Panel conducted more than 60 factfinding sessions at NASA Headquarters, NASA Centers and many of NASA's contractors. Further, we have met with congressional staff members, the NASA Administrator and Deputy Administrator, and one of our members, Melvin Stone, continued his participation with the National Research Council Panel on Technical Evaluation of NASA's Redesign of the Space Shuttle Solid Rocket Booster. A membership list of the Panel is included as an attachment to this statement.

Today we will discuss the Panel's views regarding significant aspects of the Space Shuttle Program leading to the first return-to-flight and subsequent missions; our assessment of current and projected Space Station Freedom efforts; status of aircraft safety management and operations. We shall leave for last our comments relating to the proposed Advanced Solid Rocket Motor Project, a subject we consider of prime importance.

To provide perspective on "where we are coming from" the following will help: the Aerospace Safety Advisory Panel was established by Congress to review and assess NASA's safety and safety-related activities. While most safety reviews concentrate on engineering design and quality control aspects of safety, we find that a true safety assessment must include significant factors such as organizational structures, manufacturing practices, facilities for test and checkout and the availability and use of human resources. Also, the ability of management to integrate all of these program disciplines along with cost and schedule are a part of total system safety. However, we avoid commenting on program budgeting and scheduling except as they impact safety and reliability.

Space Shuttle Program

There is no question that the effort associated with the Space Shuttle recovery program following the Challenger accident was one of the most intensive tasks that NASA and its contractors have ever undertaken. This effort by so many dedicated people should be encouraged to continue so that complacency will not occur again in the many organizations involved in flight and ground operations conducting future missions.

There should be an aggressive program for the development and incorporation of appropriate design and operational improvements which will further reduce risk. The data from each shuttle flight should be used to determine if affordable design and/or operational improvements could further increase safety. A note of caution related to our oft stated "safety first, schedule second" is that as the launch rate increases, operations personnel will probably come under increasing pressure to relax the strict observance of launch criteria in order to meet schedules. The establishment of a Directory of Operations at KSC was a positive step to ensure safety before schedule. It is imperative that the Director of Operations, Captain Bob Crippen, continue to receive full support from NASA management in this capacity. The Panel intends to monitor this area.

Prior to the launch of the STS-26 mission in September of 1988, NASA conducted a complete review of the Space Shuttle flight and ground system. Beyond a successful return to flight it also yielded a much clearer understanding of the many risks and safety margins built into the present system. This understanding, in turn, has led each of the program elements to identify modifications which would further reduce risk and improve safety. A list of some of these modifications which the Aerospace Safety Advisory Panel believes warrant more detailed study for possible inclusion in the Space Shuttle System are shown in Attachment #2. Items 2 and 3, SSME 2-duct hot gas manifold and the SSME enlarged throat diameter are typical of what the Panel considers high priority items. These two changes would significantly reduce critical stress and temperature conditions within the main engine and would greatly reduce the risk of main engine failure. Early incorporation of these two changes should be pursued by the STS management. What is needed now is a prioritization of such a list of continuing safety improvements using the large data bank developed during the post-Challenger review and the results of missions to date. The Panel urged NASA to give this effort a high priority even to the extent of reducing launch rate if necessary.

Although all of the Panel's findings and recommendations noted in our annual report are significant, it would be worthwhile to bring forward some of those that we have selected requiring your earnest attention . . . and are typical of the fourteen items noted in the report regarding the Space Shuttle.

1. Management Structure

a. Finding: Strengthening the role of NASA Headquarters (Level I) and STS program management (Level II), coupled with tighter management and budgetary controls over NASA's R&D Center (Level III), has clarified responsibilities within the total STS program and strengthened authority and accountability at all levels. Of special importance is the position of Deputy Director (NSTS) for Operations as the focal point of the highly complex shuttle processing and launch activities at the Kennedy Space Center.

Recommendation: It is essential that this more disciplined management structure--characterized by clear lines of authority, responsibility and accountability--continue in place once the launch rate accelerates in order to support NASA's commitment to the operating principle of "Safety first, schedule second."

b. Finding: The Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) function is now stronger, more visible, better staffed and better funded since establishment of the position of the Office of Associate Administrator for SRM&QA which reports directly to the Administrator. The Panel notes that the incumbent, George Rodney, is part of the key decision loops and has established the beginnings of an essentially independent "certification" process within NASA. However, there is recent evidence that budgetary pressures within the Shuttle program are causing project directors to propose budget cuts in various SRM&QA activities (e.g., safety documentation associated with the Space Shuttle Main Engine, such as FMEA/CILs and Hazard Analyses, and oversight of major STS projects).

Recommendation: Across-the-board budget cuts that jeopardize the recently strengthened SRM&QA function must be denied. Funding to maintain essential safety-related documentation of STS systems must be provided.

c. Finding: Management communications, a necessary component in achieving a successful STS program, have improved, both horizontally and vertically within NASA. In particular, the reinstatement of the Management Council, an entity that fosters direct and regular communication among all top STS managers and center directors, has brought a higher level of awareness of common problems and coordinated action to resolve them. This, in turn, has resulted in better informed and effective design certification reviews (DCRs) and flight readiness reviews (FRRs).

Recommendation: As the flight rate increases, greater attention to maintaining these improved communication channels will be required.

2. Safety Enhancements

a. Finding: To ascertain the nature of efforts to enhance the safety of the NSTS through upgrading of the five elements (Orbiter, External Tank, Solid Rocket Motor/Booster, Space Shuttle Main Engines, and the Launch and Landing Processing System) the ASAP requested compilations of such improvements from both NASA centers and their prime contractors. These lists are shown in Appendix IV.D (of the Panel's annual report) which only cover currently recommended changes for reliability and flight and ground safety beyond those installed for STS-26. Other such changes may reveal themselves as the program progresses.

Recommendation: These lists, and other changes as they are identified, should be prioritized based on attributes of safety enhancement (severity and consequence), cost, schedule and performance. This prioritizing should use the data bank developed as a result of the post-Challenger reviews and the results of the missions from STS-26 and on. Advantage should be taken of risk analysis techniques. We believe NASA should aggressively pursue this recommendation.

5. Space Shuttle Elements

a. Solid Rocket Motor/Booster (SRM/SRB)

(1) Finding: The redesigned solid rocket booster is more reliable than those used through the STS-51L mission. A number of significant areas of continuing concern were identified during redesign and testing of the new booster. These included the following:

(a) the need to eliminate possible voids and blow holes in the polysulfide adhesively bonded case to nozzle joint;
(b) a better characterization (physical properties) of the materials used in the internal nozzle ablative composite parts;
(c) the need to prevent the accumulation of slag, which plugs cowl vent holes during tail-off burning, resulting in adverse differential pressure across the nozzle flexible boot;
(d) the need to develop a resilient O-ring material (temperature compatible) for primary and secondary seals in order to eliminate the required field joint heaters; and
(e) the need to conduct a structural analysis in order to determine the criteria for safe reuse of rocket motor case segments.

Recommendation: NASA should develop a program based upon the items listed above and other significant items to improve the solid rocket motors/boosters and further reduce risk.

c. Orbiter

(1) Finding: Upon completion of the extensive loads/stress analysis it was determined that negative margins of safety existed in the Orbiter structure. In order to launch STS-26 and subsequent missions it was necessary to reduce the design flight envelope to such an extent that the probability of launch was considerably below the original target of 95%.

Recommendation : Structural margins should be improved by implementing the identified structural modifications (structural area of the wings, fuselage, and vertical tail). As pressure builds up to increase the flight rate, operating with the current structural margins might impact safety.

e. Launch, Landing, and Mission Operations

Finding: As the flight schedule picks up in FY 1989, there remains the clear and present danger of slipping back into the operating environment at KSC that helped to contribute to the Challenger accident. At the same time, the need to achieve greater efficiency and cost-effectiveness in turnaround procedures is clear. In this situation, NASA's commitment to the operating principle of "Safety first, schedule second" must be retained. If experience of the past is a guide to the future, the pressures to maintain or increase flight rate will be intense.

Recommendation: NASA must resist the schedule pressures that can compromise safety during launch operations. This requires strong enforcement by NASA of the directives governing STS operations.

Looking at the Space Station Freedom Program, in the same vein, the following findings and recommendations have been selected from the thirteen noted in our annual report:

1. Management Structure

a. Finding: The Space Station Freedom Program (SSFP) has an extremely complex organizational structure which includes a program support contractor (PSC) with system engineering and integration (SE&I) capability. NASA has not utilized this program support contractor effectively.

Recommendation: NASA should ensure that the SSFP has a strong, competent systems engineering and integration team with the responsibility and authority to pull all of the various parts of the program together.

b. Finding: There are semantic and definitional differences across the international partners and, perhaps, even the work packages. There is also an abundance of new acronyms being used. Some of these are a redefinition of acronyms used on previous NASA programs. As a result, there is great potential for confusion.

Recommendation: NASA should ensure that there are commonly accepted definitions for key terms and acronyms. Where commonality is not possible, corresponding lists should be developed and widely disseminated. Continuing control over this process is required throughout the life of the SSFP.

c. Finding: The number of interfaces, across which designs must be consistent, is very large. The responsibilities for defining design requirements to span these interfaces are not clear. This may lead, at best, to the need to backtrack in the design effort and, at worst, to the omission of a safety critical element.

Recommendation: SSFP management should clearly define the interface responsibilities for design definition as soon as possible. This will help ensure that each item is addressed as the design work progresses because the cognizant center, work package or design office will be aware of its role in the definition.

2. Safety and Product Assurance

a. Finding: The level of activity of the SRM&QA program for the SSFP appears low considering the complexity of the system design, integration and operational problems.

Recommendation: Management should make sure that the resources applied to SRM&QA activities are commensurate with the need. The SRM&QA activity must maintain its independence of operation and not be subordinated within the program.

3. Technical Issues

a. Findings: The SSFP design as baselined still does not include a specific "lifeboat" or crew emergency rescue vehicle (CERV). It is not clear whether NASA has given up on providing this capability or still has the issue under study.

Recommendation: The Panel has stated previously: "that a single purpose crew rescue vehicle or lifeboat should be an essential part of the Space Station's design."

a. Finding: There is concern that the use of the current Shuttle space suits will be inadequate to meet the time line required for the erection of the Space Station Freedom.

Recommendation: NASA should go all-out to develop the new higher pressure suit so that it can be made available for timely use in the construction of the Space Station.

In the area of Risk Management, NASA has been alert to examining all of those parameters that form constituent assessments leading to overall risk management . . . cost, schedule and performance. Included in performance are both technical and safety/reliability disciplines. In our annual report a year ago we commented on the significant progress being made in structuring the safety engineering and quality assurance functions that support risk assessments and find that a framework exists to do a risk management process for manned flight programs. This process encompasses risk identification, categorization, estimation of risk levels, definition of risk acceptance criteria and selection of risk mitigation alternatives. Our most significant findings and recommendations in the risk management area are as follows:

a. Findings: In 1988 NASA issued several NASA Management instructions and Handbooks (NMIs and NHBs) that provide policies and direction designed to improve the identification, evaluation and disposition of safety risks. In particular, NMI 8070.4 titled "Risk Management Policy for Manned Flight Program" calls for a risk management process that includes categorization and prioritization of "risks" using qualitative techniques for ratings of the frequency expectation and severity of the potential mishaps. The documents also provide for use of quantitative risk analysis to provide a more definitive ordering of risks for purposes of risk management.

Recommendation: The risk management policies and initial implementing methodologies which have been issued in 1988 need to be evolved further. Practical quantitative risk assessment and other relative risk-level rating techniques should be actually developed. They should then be applied to help define the risk levels of flight and ground systems.

e. Finding: Functional areas such as systems safety engineering at the Centers appear not to have received the resource support necessary to fulfill their responsibilities. The SRM&QA organizations at the centers appear to be relatively loosely coupled to headquarters.

Recommendation: The various systems safety organizations throughout NASA should get stronger assistance from Headquarters especially regarding financial support.

Before closing I would like to cover one other area of significant interest, the Solid Rocket Motor and the proposal to develop the ASRM. NASA has received well deserved laudatory comments on the performance of the Redesigned Solid Rocket Motor (RSRM) on the missions starting with STS-26. Examination of the instrument data and post flight inspections has not disclosed any flaws or unusual conditions in the RSRM that would indicate cause for concern about its safety and/or reliability. NASA has adopted a premise that the ASRM will benefit from advanced solid rocket motor technology and automated manufacturing methods and thus evolve into a safer and more reliable solid rocket motor than the current RSRM. It is not evident why such improvements, as they develop, could not be introduced into the current production process. In any event the current Space Shuttle schedule, if successfully carried out, would see more than 160 uses of the RSRMs before the new ASRM is introduced. With such a history behind it, any quantitative risk assessment analysis would most certainly favor the RSRM with respect to reliability and safety. In view of this situation--and because other elements of the Space Shuttle system, if modified or replaced, could contribute more to improving safety margins--the Panel believes strongly that NASA should review their development of an ASRM. Perhaps the resources of the National Research Council (NRC), which greatly assisted in the redesign of the current solid rocket motor, could be of great assistance to NASA in their reaching a final conclusion in this matter. An additional thought to keep in mind is NASA's possible use of a mixed fleet of Space Shuttle missions and Expendable Launch Vehicle missions that may be needed in support of the Space Station Freedom assembly plan. Perhaps the STS and ELVs could end up using the same new type of booster.

In summary, the Aerospace Safety Advisory Panel provides an audit and checking system. This encourages NASA to adhere to the philosophy of "safety first, schedule second" when launching Space Shuttle missions. Further, the ASAP will continue to monitor NASA's efforts to sustain this approach and to prevent complacency from rearing its ugly head in the future. With regard to the Space Station Freedom Program there is much to be done quickly in providing the basic "design-to" requirements, tightening up the organization and management activities and assuring that systems engineering and integration along with systems safety engineering are provided the necessary resources to meet their technical and administrative obligations.

Mr. Chairman, on behalf of all the Aerospace Safety Panel members and consultants, we would like to thank you and your subcommittee members for this opportunity to "have our say." We are pleased to be another set of "eyes" and "ears" and perhaps "arms" for you and for NASA in furthering the nation's goals in aerospace missions.

Thank you, and we would be happy to answer your questions or requests for clarification regarding our activities.

Senator **Gore**. Mr. Donlan, if I could just interject one point. Your expertise has long been with liquid rocket motors, correct?

Mr. **Donlan**. I would not say I had expertise in either solids or liquids. My expertise has been part of the NASA system for many years as the first director of the shuttle program. I remember we did have liquids as the initial choice for the propulsion methods.

Senator **Gore**. But you have primarily been associated with liquids?

Mr. **Donlan**. Liquids in the past several years. My associations in consulting with the Institute for Defense Analysis has resulted in some of our studies resurrecting them.

Senator **Gore**. There has long been a kind of an almost an ideological dispute of nearly religious intensity between liquid advocates and solid fuel advocates down in my part of the country.

The Baptists and the Church of Christ are often in arguments. I know my father is a Baptist and my mother is Church of Christ, so I know how that can be. And that has sort of been the way it has been at times with liquid advocates and solid advocates in rocketry I am advised.

Were there any members with long experience in solid rocket motors on your panel.

Mr. **Donlan**. Well, Dr. Himmel, who has experience in propulsion from the Lewis Research Center, might care to comment on that.

Senator **Gore**. I guess I have inappropriately interjected. Let me let you finish and then I will let my colleagues go and I will save my questions.

Mr. **Donlan**. You interjected at the right time, because I had concluded my testimony at that time.

Mr. **Thompson**. Well, senator I think it is subjective. A lot of it depends upon your experience. For the record, my experience has predominantly been in liquid propulsion systems starting back with the first stage of the Saturn vehicle, the F1. I saw a number of them blow up during the development process and managed the Space Shuttle main engine for some eight years starting in 1974. So you have got to pay attention to both. I think around the NASA and I think in the general community, all of us even, well, certainly prior to Challenger, were more suspicious of the Shuttle main engine, the liquid system, than the solid rocket motor. Since Challenger, now we certainly know more about solid rocket motors. But I think it is my assessment that I am very attracted to the simplicity of the solid motor, if indeed we can put the right facilities in place to build them right and that then leads us to the ASRM.

I think the advantages of a liquid system—you can shut them down with diagnostics—is well known, but I think when you trade off the simplicity of the solid and plus our desire to build them right, certainly for the future, as well as some things we have got on-going at Thiokol now.

I feel very comfortable with a manned shuttle system riding atop a solid rocket motor, with the teams we have got in place now and our plans for the future. So I come very strongly, even with my liquid background, in favor of the solid rocket motors for this application based on where we are now.

I might comment, we have been studying liquids I think pretty aggressively for the last 16 months now. In order to incorporate them pretty much mid-stream where we are today in the Shuttle system takes some significant redesign, not only on the pad but we would have to grow the diameter to achieve approximately the same performance anywhere from, up to 14 feet perhaps to 18 feet, depending upon whether you use LOX–RP or LOX-hydrogen.

Those are things that could be done but it is going to turn around and require additional changes on the total Shuttle system. The total cost then would go up. I think there are significant cost disadvantages to incorporating liquid systems at this point in the Shuttle program and so I think those are summary of my remarks and that comes from, I think a rather large background of liquid experience.

Senator GORE. I think earlier today in the risk analysis we saw that the SSME presents in the analysis a higher risk than the solid booster and the ESA-Hermes system for the Ariane 5 will be a solid—that is, their manned system—whereas their commercial launch vehicle, the Ariane 4, is a liquid.

I am going to refrain from here on out to let you finish, Mr. Himmel, and you Mr. Truly, and then I will go to Senator Heflin and then to Senator Garn and then myself. Did you need a chance to finish up? I want to come back to this dialog but I want to finish the prepared statements at this time.

Mr. DONLAN. I am through.

Senator GORE. Admiral Truly?

Admiral TRULY. Mr. Chairman, I will be very brief since I had an opportunity earlier to state the rationale as to how we got to the advanced solid rocket motor.

I would like to make one point though, that even though we sit here at this table debating the pros and cons of a specific program and a specific issue, let me tell you that the NASA Aerospace Safety Advisory Panel and its chairman, Mr. Joe Sutter, who Mr. Donlan mentioned that cannot be here today, has been with us in great detail through the Shuttle recovery and the fact that we disagree on certain points in this particular program does not, I think, represent a disagreement with the amount of help that we have gotten from their panel.

But we do disagree on this point and I have debated this issue internally with my center directors and with my program people many, many times. I have talked about it with members of the panel, and again I would say that on balance, between the advantages that we see for the solid rocket motor in, we believe giving us better reliability margins, plus the competition that it has already put and will put into this major national industry and finally the performance gain, on balance we believe that it is the right program for us to go ahead with at this time.

Thank you, Mr. Chairman.

Senator GORE. All right. Senator Heflin, you lead off then we will go to Senator Garn.

STATEMENT OF HON. HOWELL HEFLIN, U.S. SENATOR FROM ALABAMA

Senator **Heflin**. Well, thank you and we appreciate the fact that you invited us to come and participate in this. I have introduced a bill pertaining to the contingent liability to get the advanced solid rocket motor plant working and moving forward and I have a statement for the record.

Mr. Chairman, I want to sincerely thank you for your allowing me to participate in this hearing today on NASA's FY1990 Space Transportation Budget Request and Related Policy Issues, particularly the Advanced Solid Rocket Motor. I want to commend you on your leadership and initiative in this area and for your strong support for America's Space Program.

As my colleagues know, I am also a strong and outspoken supporter of our Nation's space program, particulary the space transportation portion of the program. The Marshall Space Flight Center in Huntsville, Alabama, manages three of the four main elements of the space shuttle system—the space shuttle main engines, the external tank, and of course, the solid rocket boosters. In that regard, the Marshall Center also manages the Advanced Solid Rocket Motor program.

In my judgment, our nation's space program will need a follow-on solid rocket motor which will enhance reliability and safety, and provide the shuttle system with a greater payload capacity, if we are to do many things in space planned for the 1990s and beyond. In my judgment, the ASRM will meet that need.

NASA has now selected a contractor to build the ASRM and, at the same time, nailed down the site at which these new and powerful rocket motors will be built. I believe we should move forward with this program without delay. This is why I have introduced legislation, S. 663, the Advanced Solid Rocket Motor Contingent Liability Act.

NASA has designated the abandoned TVA nuclear power plant at Yellow Creek, Mississippi, as the site to build the ASRM facility. This location is four miles from the Alabama state line. NASA has also indicated that private financing will be part of this contract. In that regard, contingent liability legislation must be enacted by Congress and signed by the President in order that NASA may move forward with this program. This is the legislation which I have introduced. Contingent liability can also be referred to as "termination liability."

As many of my colleagues know, whenever the federal government enters into a contract with a private concern and the contract contains any element of private financing, the federal department or agency initiating the contract must have the authority to cover any losses that the private contractor might incur in the event that the government, for reasons of its own, terminates the contract.

In the case of the ASRM program, NASA's original intention was to develop a Government-owned contractor-operated (GOCO) facility at which to build the new powerful rocket motor. However, the Reagan Administration, through OMB, decided private financing of the facility should be considered. As a result, contractors bidding on the ASRM program were also required to propose bids which offered private financing options to NASA for construction of the facility. Thus, even at that time, there was no question that the issue of contingent liability would have to be addressed.

The language in my bill is substantially the same language that had been included in the Senate-passed version of the NASA authorization bill for Fiscal Year 1989. However, in the closing days of the 100th Congress, the House stripped this important portion from the bill.

In order to resolve this matter, the distinguished Senator from South Carolina and the chairman of the Commerce Committee, Senator Hollings, Dr. Fletcher, the administrator of NASA, senior officials at OMB and I worked diligently in the last days of the 100th Congress to establish an agreement ensuring that the $27 million authorized in the bill for the construction of the plant could be used as interim contingent liability should it become necessary. Legislative history was made to establish that the $27 million would be available for contingent liability. This was established through discussions and agreements between NASA, senior officials at OMB and backers of the Senate bill, as well as the author of the Senate bill.

In order to finalize these discussions and agreements into legislative history, a colloquy occurred between the author of the bill, Senator Hollings, and myself on the floor of the Senate during final consideration of the NASA authorization bill after it had come back from the House in order to clearly establish that the $27 million in construction money could be used toward contingent liability. With this assurance, NASA went ahead and conducted a fair and open competition that would allow the consideration of both privately and publicly financed facilities.

NASA officials have relayed to me since that time that this action kept the program from being killed. However, we must realize that the availability of these monies from the construction aspect of the program was merely for the interim and temporary relief as it would relate to contingent liability.

Now that NASA has selected a contractor for the ASRM and a privately financed option, in order to proceed with the program, I understand that it is necessary to have language substantially similar to that which was contained in the Senate-passed bill which would clearly provide for contingent liability over the lifetime of the project. Therefore, my legislation is necessary and needed. I intend to ask the NASA panel here today if that is, in fact, the situation relative to the ASRM and contingent liability.

Mr. Chairman, again, I appreciate the opportunity to appear at this hearing today. I strongly support the ASRM program and want to see it move forward without delay. Again, I commend you on fully discussing this program and taking the initiative to air out some important issues relating to the program which should be discussed.

Thank you, Mr. Chairman.

I have some questions first maybe to either Admiral Truly or Mr. Thompson, and I am delighted to see both of them here. They are professionals in the true sense of the word, in NASA, and to recognize that they have been selected to lead our space program during this Administration to me is very gratifying. They are very knowledgeable and I have great respect for both of them and we look forward to working with them in the Space program.

But let me ask this question. Can NASA responsibly negotiate, or sign a contract, on the advanced solid rocket motor without the contingent liability language contained in the bill that I have introduced being enacted?

Mr. THOMPSON. Senator, let me respond to that and then if we need to get into any detail I can get Lowell up here, but we do need that language. We need it rather urgently, as soon as we can, so that we can move ahead. We are continuing our fact-finding with the selected contractor now, anticipating a favorable response from the Congress. But we will need it, and we will need it just as soon as you can give it reasonable deliberation and we can answer whatever questions we need to.

Senator HEFLIN. Has NASA informed the contractor—which would be Lockheed and Aerojet in this instance, who have been selected—to cease all activities until the contingent liability language is enacted?

Mr. THOMPSON. I do not believe so. I am sure that is not the case. No; we are pressing on again anticipating a favorable response and a little bit trying to maybe hedge a bet relative to the sense of the Congress and we are going to continue our fact-finding. But pretty soon we are going to get a hard point where we want to sign up and we are going to need, certainly, your support at that point.

Senator HEFLIN. Will the addition of the advanced solid rocket motor to the Shuttle reduce the missions required to launch the Space Station Freedom and the extra vehicular hours' activity necessary to assemble it in orbit?

Admiral TRULY. Because the advanced solid rocket motor has not had final approval the Space Station program—and that is not my responsibility, at least not today—the Space Station program has not assumed its availability.

I certainly believe that the additional 12,000 pounds per flight has got to have one of two benefits to the Space Station assembly, both of which would be good. One is to provide more margin as the Space Station eventually gets developed in case it should grow in weight and then potentially to reduce the number of flights.

I will say that we have recently completed a study within NASA looking at the Space Station operation and the operational years—in other words, 1998 and out—where we have a major performance problem. With present projected station weights it is going to need to be resolved with either expendable launch vehicles doing logistics, but one obvious solution in going through that study is the advanced solid rocket motor, if it delivers even about three quarters or so of the projected performance that we have.

Senator HEFLIN. If the advanced solid rocket motor reduces the number of Shuttle missions required to launch the Space Station Freedom and the EVA hours to assemble it, does this reduce the total risk to the Space Station project?

Admiral TRULY. Certainly, EVAs that you do not have to accomplish, or flights that you do not have to fly, will reduce risks.

Senator **Heflin**. Are there any safety advantages to the advanced solid rocket motor as opposed to the redesigned solid rocket motor?

Mr. **Thompson**. Senator, I think it gets back to the producibility and taking a lot of the manual operations out. The people at Thiokol are doing a super job today, but there are a lot of manual operations and any time you do it to the extent that we are doing it, then you are setting yourself up for a potential problem.

In keeping everybody doing 1,000 percent of the job for the next several decades which I personally believe we are going to be flying the Shuttle, I think we need to put the facilities in place so we can get the right enhancements and productivity and certainly minimize that risk.

So on balance, certainly I would come down that just because of processing there are going to be significant advantages to the advanced solid rocket motor. As I stated earlier, it is a very simple design and it is very sensitive to the way you make it.

Senator **Gore**. Let me interject that if other members of the panel wish to respond to any of these questions, feel free to do so within the time constraints, because we want to get to Senator Garn, but do not feel like you have to be silent.

Mr. **Donlan**. Well, our objections really are not so much to the ASRM per se, but I agree that I think the Shuttle is going to be around for several decades and our view is that the long-term improvement can be acquired during which time the existing solids might be used until such time as this new development takes place.

There is a little apprehension we have that this is a short-term solution rather than a long-term solution and that it was the long-term solution that we were really asking if NASA was satisfied they had taken a long-term look at before making the decision to go this route.

Senator **Heflin**. It is my information that one of the safety improvements of the advanced solid rocket motor over the revised solid rocket motor is that the advanced will eliminate some 175 catastrophic failure modes by avoiding the need for Space Shuttle main engine throttle changes during the period of maximum dynamic pressure. Can either the redesigned solid rocket motor or a new liquid booster achieve these same reductions?

Mr. **Thompson**. In order to achieve that with the current solid rocket motor we would have to essentially do a significant amount of redesign and if one were to embark on a new start of a liquid system, certainly I think you would incorporate that feature.

But you are right on mark. It does significantly simplify some other systems within the Shuttle that we worry about, specifically the main engine. So just from that synergistic effect I think it has got a lot of pluses.

Senator **Heflin**. Have the two of you, in particular you, Mr. Thompson, who is charged with propulsion transportation in the NASA program, have you reviewed very carefully the report of the Aerospace Safety Advisory Panel and after reviewing it, is it your judgment that you should proceed with the advanced solid rocket motor?

Mr. **Thompson**. Yes, it is. I think we just have an honest difference of opinion. There are a number of areas that I think we should focus our attention on improvements. Right at the top of my hit parade are the propulsion systems, the Shuttle main engine and the solid motors.

I believe that 95 percent of the times that we have a catastrophic failure it is going to be in one of those two systems because that is where the action is. That is where the heat is generated, that is where the clearances are tight, that is where the turbine speeds are at higher RPMs so that is where our attention should focus.

I think we are doing that and we have been doing it over the last, almost decade now, in the Shuttle main engine. It has been the most improved component of the Shuttle system and it is continuing.

We are working on advanced turbopumps. Pratt & Whitney is working on those. It will take us several more years to incorporate them, spending a little less than $100 million annually on that project. I think we now need to do the same thing with the solid, not only at Thiokol in the near term, but in the advanced solid rocket motor over the long haul.

Senator HEFLIN. I have a couple or three questions to the Aerospace Safety Advisory Panel. Has this panel had a briefing on the proprietary design submitted to NASA for the advanced solid rocket motor? Of course you had a competition and you had the Lockheed Aerojet team win and they did so on their design.

Did the panel have a briefing on the proprietary designs before you made your findings and have you made a comparison with the current revised solid rocket motors 'reliabilities?

Mr. DONLAN. Sir, we did not have briefings prior to the position we took in our report of this year. We did have, fairly recently, exposure to the salient features of this system, but basically on the reliability standpoint it is a matter of documented experimental reliability versus paper expectation and some of our views were colored by the fact that paper probability estimates sometimes do not materialize when it gets around to really building the hardware.

Senator HEFLIN. Would the use of a liquid booster for the Space Shuttle cause significant modifications to the Kennedy Space Center's facilities? My information is that if you want to go to the liquid boosters, that estimates place the cost of modifying the Kennedy Space Center facilities to some $500 million and it would take two years longer for that to take place relative to the use of a new, advanced solid rocket motor. Would it require significant changes at Kennedy in cost as well as a delay?

Mr. DONLAN. Sir, I have seen some of those studies. As far as I can recall, it would take longer, I believe. Maybe three years or more to develop it. The modifications to the systems, from the studies I have seen from NASA, are not that significant, as I recall them. But their main point was whether you could delay them two or three years as opposed to the urgency of putting them up quicker, which you can do with the new ASRM.

Senator HEFLIN. It is my understanding that NASA feels that the safety and reliability of the current redesigned solid rocket motor is being maintained through extraordinary management efforts and they are concerned that this level of emphasis will be difficult to maintain if the advanced solid rocket motor is not introduced expeditiously. What is your position on that issue?

Mr. DONLAN. Well, I am not sure I understand completely the implication of the question, but the fact that we will be using the current redesigned solid rocket motor for the next five or more years indicates to us there is enough feeling of safety and reliability in it so we can proceed with it.

Senator HEFLIN. I would just like to introduce into the record some figures on estimates of cost at Kennedy and the delay matters.

Senator GORE. Without objection.

[The information follows:]

Program Finding: The Shuttle using liquid fueled boosters can, with proper planning and expert program execution, accomplish 122 launches from 1996 to 2006 at KSC.

1.2 SIGNIFICANT STUDY FINDINGS

The significant study findings are shown in Figure 1.2-1.

Finding 1: The transition from STS/SRB operations to STS/LRB operations in a non-disruptive manner to the ongoing (phase down) STS/SRB operations presents an unprecedented NASA/KSC challenge. Transition has significant schedule and cost risk. KSC needs a dedicated activation team for activation and transition planning. This team should follow through to implement the new booster operations.

Finding 2: New LRB facilities plus some modifications to existing facilities are required. These include 2 new Mobile Launcher Platforms (MLP), a new Horizontal Processing Facility (HPF) and modifications to the Launch Pads A and B.

Finding 3: Seventy percent of the LRB preliminary design requirements have significant ground systems implications and most design features drive ground systems design (KSC non-recurring cost). Schedule risk and recurring costs are relatively insensitive to LRB design options, but LOX/LH2 is the KSC preferred propellant choice for LRB.

Finding 4: The LRB has a potentially significant and shorter integration timeline on the MLP in the VAB, compared to SRB. This potential reduces launch rate risk (providing the ability to increase launch rate) and launch schedule risk.

Finding 5: Preliminary analysis has identified LRB launch pad clearance problems (metal to metal contact) during ascent. The extent of engineering required to achieve a solution and the magnitude of the solution is unknown.

Finding 6: Cost and launch schedules are sensitive to program planning factors and the degree of achieved booster processing friendliness. Reductions in cost estimates and schedule risks may be realized through the implementation of sweeping innovation (other than currently planned processing enhancements i.e., electronic scheduling - LPS II).

Finding 7: The KSC LRB program costs are approximately $1 billion dollars non-recurring and $1 billion dollars recurring, for a total of $2 billion dollars over a ten-year life cycle (122 missions).

Figure 1.2-1. Study Findings.

Senator GORE. We will perhaps come back for a second round, if that is possible. We are very pleased, as I said earlier, to welcome Senator Garn to these proceedings, since he is one of the two veterans of space flight in the United States Senate and one of the real experts in the country. We are delighted to have you join with us.

STATEMENT OF HON. JAKE GARN, U.S. SENATOR FROM UTAH

Mr. Chairman, I want to express my appreciation for you inviting my participation in this hearing on the NASA proposal to develop an Advanced Solid Rocket Motor (ASRM). I think it unfortunate that in the Congress we too often confine ourselves to the particulars of our own committee assignments and jurisdictions, and rarely venture out beyond these confines to gain a broader perspective on issues. Unfortunately, with our growing budgetary problems, it has never been more critical that we view the choices before us in as large a context as possible.

As a wise politician once observed: "Where you stand depends on where you sit."

But as we are increasingly forced to choose between deserving and attractive alternatives, we can no longer rely on the simple justification that the program we advocate has merit. Indeed, we must choose among the meritorious to find which ranks higher than rest. And we cannot simply be satisfied that our choice best fits the programmatic requirements of the activity before us, but must ask whether this choice is an optimal one in such diverse contexts as economic, budgetary, and scheduling constraints as well as larger National interests.

In short, where one sits, no longer covers enough ground on which to confidentially stand.

I look forward to this opportunity to share with you my views and concerns, and more importantly, to hear yours. Again, I appreciate this opportunity to participate in your Subcommittee's hearing on this important matter.

Senator GARN. Thank you very much, Mr. Chairman.

Again, I do wish to thank you for your courtesy. I am not sure Admiral Truly and the witnesses are happy after having to confront me last week in the Appropriations Committee. They thought they had gotten away from me and they get me again this particular week.

At the outset, let me put in my disclaimers that I always have to, particularly when I get on the issue of ASRM. I get accused of all kinds of things and started out, several years ago I was being accused of being part of the Utah Mafia and seeing that Thiokol got the contract for the current solid rocket motors.

The only answer I have to that is, I was mayor of Salt Lake City when the contract was granted. I had not been elected to the Senate for two more years after that and so I plead not guilty to that particular charge, unless I was the most powerful mayor in the United States and had great influence over the deliberations of NASA and the U.S. Congress.

Senator GORE. You were Chairman of the National Conference of Mayors at that time, as I remember.

Senator GARN. I was president-elect. Tom Bradley was the president.

Second, on the current issue, Thiokol is going to continue to build the current set under their contract for probably at least eight to 10 years so there is nothing endangered there. Plus, it appears they are going to be a major subcontractor and get about 25 percent of the development contracts during the initial phases of the ASRM program. So Thiokol does not appear to need any help. Regardless of what scenario we go with, Thiokol is in good shape.

Having said all of that, though, I would make no apology for defending Thiokol in any event. Like all of us do, we certainly try to promote and help businesses in our own states and I was only elected to represent Utah, not any other state. So now that I have gotten my standard speech out of the way——

Senator **Gore**. The senator's time has expired.

Senator **Garn**. Let me get into the specific issue. In June of last year the Appropriations Committee held a separate hearing on ASRM and in reviewing the transcript of that hearing, what I have been struck by is how little has changed. We are still talking about the same thing and unfortunately trying to relate it to the overall budget constraints. We are talking about the same problem, once again, that we were last year at the time, except it is worse this year.

Last year we also had quite a stir and a debate over, even if you go ahead with ASRM, whether it is GOCO or contractor-owned, privately financed and this year the difference there is that you propose private financing for the construction of the plant, requiring that parts of the plant as they are completed be turned over to the contractor, from the contractor to NASA. This is not lease-purchase. In fact, I am not quite sure what it is, but I am sure it is not privatization.

Finally, we have got to grapple with the issue of spending over a billion dollars to improve a solid rocket motor, whether that is prudent or necessary investment in light of the fact that the Senate Budget Committee has removed a billion dollars and as we talked last week, Admiral Truly, unless we are able to turn that around in the Appropriations Committee there is no Space Station. There simply will not be one.

You are not going to eliminate the aeronautics budget. You cannot take that kind of a cut in the Shuttle operations. It ends up one place. It kills the Space Station unless we are able to get that.

So, at minimum, if we go ahead with a billion dollars on ASRM, however it is devised, however the contracts are, it seems to me that it either makes impossible or it certainly constrains funding for other improvements, continued improvement of the current solid rocket motor, other components of the Shuttle system and other alternatives that are being discussed of liquid boosters or something that you know that I have been very much in favor of for a long time, Shuttle C, which—so is NASA, but funding constraints are the reason we are not doing a lot of these things.

Let me go into each one of these. At the time of last year's hearing the House had proposed a $200 million cut in your request for the Space Shuttle program. Frankly, we got lucky and as you remember Ted Stevens and I and some others were able to get $100 million out of DOD to replace Shuttle operations so the cut was not $200 million. But as I mentioned the budget situation is worse this year, on certainly the likelihood of further DOD transfers, after getting $2 billion out of them for the replacement orbiter and $100 million for Shuttle operations.

So if we decide to go ahead with your $121 million request for ASRM this year, it seems to me that the only place you are going to get it is out of Shuttle operations. I do not know where else you are going to take it. So at the same time we are talking—that is why I am not going to argue liquid versus solid with any of you, particularly with J.R. Thompson. As a banking and finance major I do not know anything about that, although Dick Truly and I are the only ones in the room that have ridden the old solid rocket motors. That is all I know about them. It was a nice, great, exciting elevator ride up.

But that would be my first question. Where are you going to get the $121 million in light of the overall budget considerations? I cannot see it in my analysis of the budget, and watching it for years, and take it out of Shuttle operations so it is not going to rob some of the other things that you want to do.

Admiral TRULY. Well, if I might comment. The 1990 budget as it is put together, and I am here attempting to justify it today for the Office of Space Flight, includes the advanced solid rocket motor in that portion of the budget. But you are exactly right, the budget is extremely tight and that is why we have deliberated internally so many times as to whether or not the advanced solid rocket motor should continue to be brought forward for consideration by the Congress.

Nevertheless, with the programs that we have approved and ongoing, and the advantages we see in the advanced solid rocket motor, that is the reason that we did prepare a budget that includes ASRM in the total Office of Space Flight request.

Senator GARN. But that was for a billion dollars more.

Admiral TRULY. Of course, that is with the total NASA request in the 1990 budget, yes.

Senator GARN. That is my point. That budget, at least at this point, is a billion dollars down. So the real question is, do you want to spend $173 million or $121 million and take it out of Shuttle operations or out of Space Station Freedom, or so on? You know darn well we are not going to get the whole billion back, no matter how hard I try. We are not going to be able, in this budget climate, to get it back.

So now I am trying to, again, not argue liquids versus solids or anything, I do not have the technical background to do that. But in terms of the priorities you are going to face I do not understand that we are going to go to an ASRM. You lost $111 million last year in the main engines. You are requesting, what, $96 million to get that back. Everybody has agreed that we are probably more at risk from the main engines than we are from the solid, so a priority to me is to continue to improve those main engines as rapidly as we can.

So my point, that if we go ahead with ASRM, a new start, and the budget only has about 1 percent for new starts—it is funding existing programs—and we face the cuts, that we are going to face, whether you or I like it or not, do we spend this much money—when we are facing those cuts do we take it out of Shuttle operations? Do we take it out of improving the main engines?

Admiral TRULY. Well, again you are exactly right and before this year is out and in another chair I am certainly going to have to face with your help what is going to happen to the future of the space program with regard to this.

Senator GARN. Well, let me get very specific. Where do you place, in priority, improvements to SSME compared to the ASRM program, if you have to make that choice?

Admiral **Truly**. Our OSF budget includes what we think are adequate funding for the SSME program along with the ASRM project.

Senator **Garn**. But that is in your request.

Admiral **Truly**. That is right, in the Office of Space Flight's request, which I am here today talking about. That is right. It is included in that.

Senator **Garn**. But I am saying, okay, you are probably not going to get your request. Then what is your priority if you are forced to choose between ASRM and improved SSME? What are you going to do?

Admiral **Truly**. I cannot answer that question, because as the Office of Space Flight I do not have that issue in front of me. I believe that the investment in the SSME that we are putting into it is absolutely mandatory and based on the balance of the increased reliability, the competition in the industry and the needed performance, I believe that the ASRM is a needed program and that is why we are here defending it.

Senator **Garn**. I understand that. J.R., hypothetically, if you are faced with that choice, what are you going to do? If I ride it again I want—from what I have learned and did not know at the time I want to improve the SSME more than I want to worry about a new solid rocket motor.

Mr. **Thompson**. Senator, let me take a shot at it. Admiral Truly has answered in his current job, so let me do the same as Director of the Marshall Center, that is responsible for these propulsion systems.

If something has to be done within the Shuttle program, I think right at the top of the priority list are our propulsion systems, both the Shuttle engine and our solid motor improvements. I think we would have to take a look at what we are trying to do in terms of flight rate and that kind of thing.

I think we have learned since the Challenger accident that we at NASA should try to do the jobs that we have got well and if indeed push comes to shove and we have got to do something and we need to stand back and address the overall, perhaps launch rate, those would be my priorities.

We have got to make sure we are doing everything we can to make sure that we have got a good highway to space, because that is holding up a lot of the rest of what NASA does. If we do not have a reliable Shuttle, primarily in the engines and in the solids, then Space Stations and AXAFS and Hubble Space Telescopes are going to be on very shaky ground.

Senator **Garn**. J.R., I do not disagree with you at all. I sat here for the last five or six years just trying to hang on with my fingernails, keeping NASA funded and I do not very often disagree because I do not have the technical background. But in light of all the budget constraints I have a very hard time understanding why we are pushing ahead with this when it appears that it is going to rob other programs. Because I agree with Dick Truly, it is mandatory that the SSME improvements continue and certainly your general statement, we want the reliability of getting into space.

I have some concerns, not from expertise in this area but expertise as a pilot. I do not know how in the world you can guarantee this is going to be safer when it has not been tested. That is where we get into what they are talking about. You have a known quantity. However flawed the O rings may have been, the improvements have been made. You have one that has flown over and over again and will fly 160 some odd times before we ever get to an ASRM.

You have got to go through all that testing. I used to hate new airplanes. I loved the old ones that I had flown a lot of times. I used to hate engines that had come out of overhaul. They would usually fail within the first 200 hours. Just from my aviation background, for people to sit here and tell me that a newly-designed motor that has not yet been tested is going to work, I mean I can talk about the engineers at Chrysler and General Motors and all these wonderful things that were going to take place on a drawing board but do not.

I think that is really what they are getting into when the recommendation is, the Aerospace Safety Advisory Panel (ASAP) recommends that NASA review its decision to procure the advanced solid rocket motor and postpone any action until other alternatives, including consideration of long-range objectives for future launch requirements have been thoroughly evaluated.

It is not clear to ASAP why NASA is proceeding with this plan to develop a new and expensive solid rocket motor, especially when there are still many elements of the STS system which if modified or replaced would add significantly to the safety of the operation. Obviously, an honest difference of agreement.

But I happen to think, from my background and experience, that with the constraints of NASA's budget and trying to save a Space Station, I hope we can. But I am honestly not sure whether we can or not. Then you do not need your 12,000 pounds any more. You have not got any big components to carry up there. If we had unlimited money this would be an entirely different argument and I would be saying sure, let us go on to a more advanced solid rocket motor. No doubt about it.

But you are going to have to make, the both of you in your new jobs you are going to have to make some extremely difficult choices, because I do not have the ability to get you enough money to do what you really want to do and that is where I am coming from.

That if we have to go ahead with this and make other choices—cut back on SSME, Shuttle operations—I do not think it is worth doing under those circumstances, particularly when I cannot be convinced that a rocket motor that has never even been tested, is still on the designing board, will be safer than a current SRM that continues to have improvements made for a lot less cost.

That is where I am coming from and it is probably the first big, major disagreement I have had with NASA in years. I just do not understand the logic of where you are coming from on this one.

I am sure my time—I should stop at this point and let my distinguished colleague from Mississippi speak.

Senator GORE. Let me thank you again for your participation. We wanted to make sure that we had a good airing over the disagreement here.

Senator GARN. I did not say I was through. I just did not want to continue to dominate the time.

Senator GORE. I do not want to leave unchallenged the impression that anyone might get that there are not others of us who are also eager to go to bat for NASA and help get the funding that is necessary for a vigorous American role in space and that is true on the House side as well, with Congressman Whitten and others who are very supportive of you.

Senator GARN. Would you please mention the Appropriations Committee? That is where I need you and Howell Heflin.

Senator GORE. I think Congressman Whitten does have something to do with the appropriations. The opening statement from Senator Cochran is in the record and we can run down the list, but just in spite of these Senators' heroic efforts in behalf of NASA, there are others of us——

Senator GARN. Well please, Mr. Chairman, let me interrupt you to say that if I was trying to indicate that I did it all by myself, that is ridiculous. I have been in the Senate for 15 years and no single individual—and so please, if I indicated that, that was not my intention. Because I could go through the list as well.

There would be no program at all without Eddie Boland and I am very, very sorry that Eddie is not still over on the House side, so if I gave that impression I certainly did not intend to because I have been part of this process long enough to know that it takes 51 votes and it takes a majority in each of the Committees and it takes a lot of people to do it.

Senator GORE. Let me ask just a couple of questions and then we will turn to Senator Lott. The staff of our subcommittee has for the last several weeks talked with people in the solid rocket motor and liquid booster rocket business to try to get a good handle on the benefits of each system and the status of each system and to be quite honest, our conclusions are that there are indeed benefits associated with each type of system that are unique to each system.

Liquid boosters can be shut off and tested on the pad and solid rocket motors have few moving parts or fittings. It appears that a review of the history of flight failures of these two systems shows that liquid engine failures tend to be subsystem failures—the plumbing or control systems. And solid rocket motor failures tend to be the fault of improper processing.

I should note that a report soon to be released will indicate that when one examines the inherent qualities of the two approaches, there is no difference as to the uncertainty of a catastrophic failure of a liquid booster or a solid rocket motor. This report I am referring to was prepared for the Air Force and for NASA.

One of the factors that greatly affects the reliability of each system and the safety of each system is the degree of uniformity involved in the production process and the production standards. Now, the proposed ASRM plant is to be highly automated, if I am correct in so asserting, and designed to produce a product of the very highest uniformity. Is that correct?

Mr. THOMPSON. Yes, sir.

Senator GORE. Now, the assertions earlier from you, Mr. Thompson, in the hearing last year before the Appropriations Subcommittee that the first advanced solid rocket motor produced in a modern facility would be safer than the 200th redesigned solid rocket motor produced in the current facility—and that is a quote—was based primarily on this factor. Is that correct?

The current Thiokol activity is man rated, not automated. There is a great deal of human hands-on manipulation of parts, et cetera and the cost of going back and retrofitting that activity to the automated, more standardized method, is much greater, if I am not mistaken, than starting a new, highly automated plant, which is the reason for the location decision in the first place.

But the primary difference is the ability to get high production standards and uniformity from a highly automated process compared to a process that has lots and lots of human beings involved with their fingers and eye-hand coordination, et cetera. Is that the basis of it?

Mr. THOMPSON. That is correct.

Senator GORE. All right. Now, this issue is significant because it relates to the usage issue. The Aerospace Safety Advisory Panel seems to feel that NASA should utilize the existing redesigned solid rocket motor and not develop an advanced solid rocket motor. But when you look at usage, if the Space Shuttle were to continue to fly to the year 2010 at a launch rate of about 12 per year, which is a reasonable assumption for a four orbiter fleet, it would utilize 480 motors, two motors for each Space Shuttle launch.

Assuming the ASRM came on line in 1994, we would use, then, approximately 160 redesigned motors between now and then. That means more than 300 advanced solid rocket motors would be manufactured under the proposed contract and that is a significant number of motors and represents, in my view, a significant reduction of risk.

I will submit some questions, some further questions for the record and if we have time I will come back to myself for some more oral questions.

My colleague, Senator Lott, has been very patient and I want to recognize him at this point.

Senator GARN. Mr. Chairman, you have been very kind to me and more than generous with the time of the Committee considering that I am not a member, and so what I would like to do is ask unanimous consent that the remainder of my questions be placed in the record and not take more of the Committee's time.

Senator GORE. Absolutely.

Senator GARN. In light of the fact that the witnesses waited for us for nearly an hour.

Senator GORE. Well, we will certainly afford you that courtesy and we assume the witnesses will in fact respond to these questions for the record and the Committee will have further questions for the record also and while they waited, the Senator also has waited patiently and the investment of time in this hearing is characteristic of his devotion to this set of issues for lo, these many years. The Senator from Mississippi.

Senator LOTT. Thank you, Mr. Chairman. This hearing and this whole process is especially educational for me, since I am a new member of the Committee. Although I have been close to NASA and its operations for a long time I have not been able to get into the details and hear this type of discussion before, so certainly I do not have the knowledge that the gentleman from Utah has and I do not know too much about this protracted debate that has gone on for years, apparently, between liquid versus solid. But let me just ask you a few questions.

Number one, how long have we been going through this debate of liquid versus solid and has the decision not been made once or twice and why do we continue to debate it? I thought the decision was made?

Admiral TRULY. Well, I have only worked in the space program for about 25 or 30 years and I am sure that is eclipsed by others, but it has been going on forever, frankly.

Senator LOTT. Well, the decision has been made twice to go with solid.

Admiral TRULY. In the Space Shuttle program—and I was not around at the time that decision was made—it was made to eventually go to a solid design. We have many systems that use each.

You can find examples—as a matter of fact the testimony of the ASAP members that are here, without question as they went through it I had to agree as I listened to it, except for the final conclusion and that is that in the final balance we believe the program is—we need it. It is worth the expenditure and I believe, in paraphrasing their views, is that they believe that if that money were available it could be spent on other items that would give us more safety advancements.

But in answer to your question, to my knowledge solid propulsion versus liquid propulsion has been going on since the dawn of the space age.

Senator LOTT. But you have made a decision to go with solid.

Admiral TRULY. That is correct. The present Shuttle system is designed and certified to the solid rocket motor use.

Senator LOTT. That is what we have you for. That is what we have NASA for, so that you will evaluate all the conflicting positions and testimony and pros and cons of the systems. But sooner or later you have to make a decision and we cannot make that decision for you. That decision has been made. So without knowing all the arguments pro and con on the liquid versus the solid, the decision has been made by the agency to go with solid and so I am satisfied with that.

Now, it has been suggested with regard to the ASRM that maybe it has not been thoroughly evaluated. I find that amazing. I mean, surely, knowing you two gentlemen and your agency it has been evaluated and reevaluated and certainly thoroughly evaluated, has it not?

Admiral TRULY. I have spent more of my personal time on the advanced solid rocket motor in the last three years than any other single program that has been under debate in the Office of Space Flight.

I do not know what Arnie and J. R. would say, but we have been over it over and over and over again.

Senator GORE. Will the Senator yield?

Senator LOTT. Sure.

Senator GORE. By contrast I thought it was very significant that in response to the questions of the Senator from Alabama you, Mr. Donlan, and you, Mr. Himmel, testified that your panel did not evaluate the design and the latest plans and specifications for the advanced solid rocket motor and did not go to the Marshall Center and were not briefed on the proposal.

Do you review that as a weakness in the ability of your panel to reach a judgment about a system that you have not evaluated?

Mr. **Donlan**. I would say that we would not question whether it has been thoroughly evaluated or not, and our position is whether it was necessary and whether in the time frame on the long-term future of spaceflight whether enough of the alternative propulsion systems had been studied to the same depth.

Senator **Gore**. Well, now, you two in preparation for this hearing decided to get a briefing on it. If you had the job of the panel to do over again, would you get a briefing on the ASRM and the details of it before giving your report? Would you have done a better job if you had done that?

Mr. **Himmel**. I do not think we would have done a better job, sir, but the thing is we could not get a briefing because it was under the SEB requirements, and we are not privy to the SEB deliberations or the proposals, and you cannot do that, number one.

And, number two, our position, as we tried to write very clearly in our report, was based upon the thesis that the purpose of the ASRM development was improved reliability only.

Now, I underscore only and on that basis when you contrast and Senator Lott raised the point—when you contrast an analytical probability or reliability number which you get during the preliminary design and conceptual design which goes on in making your proposal and the features where it is contained, you get a number, but there are no data for that particular design with which to support the results of that analysis.

Senator **Gore**. But if the Senator will indulge me just a moment more, the key factor, as noted earlier, is—has to do with the production standards and the reliability of performance that can be improved by an automated, extremely reliable standardized production procedure which could only be evaluated and the advantages of which could only be recognized after and during the kind of briefing that you all were pursuing.

Mr. **Himmel**. I have to disagree slightly. These processes do not, in fact, exist in their totality today. And the evaluation that we were referring to is the evaluation of prospective evaluation as contrasted with one based upon data from actual test results and the confidence level which you can attach to the prospective analysis results and the data have to be different in favor of the actual data, and that was our sole contention.

Senator **Lott**. Let me ask, Mr. Thompson, is it needed? The question was raised whether or not it was needed. In your opinion, is it needed?

Mr. **Thompson**. I certainly think it is. Number one, I am very proud of the work that Marshall and NASA and the aerospace team and Thiokol has done in the redesign.

Having said that, even though we have gotten good results, I do not get giddy after four successful flights. We have got a long way to go. I will probably walk out of this room today and go back at Marshall and be working problems like thinning of insulation that we are still having problems with because of the manual process and decisions that we have got to make daily in dispositioning a material review actions. There are too many of them. And that is what we have got to correct with the automated process.

It is crazy to continue over several decades with technology that is 20 years old. We are setting ourselves up for a problem in my judgment.

Senator LOTT. I will not pursue that any further. That was perfect. I will just leave it right there.

Now, assume we go forward this year and in the next few years to what—towards the ASRM. When would that actually be available?

Mr. THOMPSON. I think as Lowell Zoller indicated earlier, if we stick to the guidelines we have gotten from Arnie Aldrich for fiscal year 1989 and 1990, we are probably looking at a slip no more than several months beyond what we had earlier projected. But, either in late 1994 or early 1995.

And, as the Senator indicated, we will be flying off today's solid rocket motor for several years beyond that.

Senator LOTT. That, again, is my point. I mean, if we go forward aggressively beginning today without any slippage or mess-ups by Congress, we will not have it before 1994 or 1995. So, in the interim we have got to continue to work with what we have, make modifications, and patch it up and repair it as best we can.

But we do need, if we are going on into the next century with these programs, we are going to need an improved system, as you have described it, and the longer we put it off, the more it is going to cost, the more we are going to have to continue to modify and work with the ASRM, is that not true?

Mr. THOMPSON. Yes, sir.

Senator LOTT. And is that not why you want to go ahead and go with the ASRM because we do need to get started with that next generation?

Mr. THOMPSON. But it is certainly my belief.

Senator LOTT. On the budget questions I do not think we can expect you to sit here today and say oh, well, if forced with eliminating one or the other, I will make this decision. You are not there yet.

You have done your job. The administration has done its job. Whether we agree or disagree with it, now it is up to us to do our job and to support as best we can if we agree with you the budget proposals you have.

So, I hope we do not force you to that decision to choose between one or the other, and you might not make that choice. You might make the decision to make some changes in a number of areas that would not be cause for the elimination of one or the other.

And so, I am not going to ask you to make that kind of decision. I support these other programs, but I would not want anybody to ask me to make a choice now. And I think we just have to work our way through this, and I appreciate the job you two gentlemen have done and the job the agency has done and as a new member of the committee and a member of just learning about all of these different systems, I intend to support what you recommended.

Senator GARN. If the Senator would yield just on that question.

If you listened to the nature of my questions, they were not directed to arguing the engineering merits of liquids versus solids or any of that, but trying to place this issue in the context of the budget problems.

And obviously you are right, Senator, they do not have to answer that question today. And all I was trying to indicate, when you are down on that Appropriations Committee, not getting the 302(b) allocation that is necessary to take care of veterans, EPA, Superfund and housing that we deal with that NASA is lumped into, that is the context that I am trying to place this in because I am not going to be here arguing against an advanced solid rocket motor any more than I would improved aircraft if you had sufficient money to do all of those.

And we are going to face that choice without the substantive arguments back and forth over liquids versus solids or whether it is worth it, and that is why I was bringing out the SSMEs and the other choices.

But, if you get into the details of that budget, NASA has been making very difficult choices for a long number of years.

The criticism they get from going to the shuttle and not having a balanced fleet of ELVs, that was never NASA's desire. They wanted both. We only gave them enough money—and if they had chosen ELVs, then you would have a crowd out there saying we should have had manned spaceflight. So, they cannot win.

I am not blaming them for the lack of funds. They cannot win. But even if we get part back of what the Budget Committee has given us, which is inadequate, very quickly in the next couple of months they are going to be faced with choices of this kind, and that is the nature of my questioning, to place it beyond the individual issue into the overall context of how we are going to make decisions.

Senator Lott. Well, I have some suggestions on that, and I will wrap up because I know we are late here. But I just want to say I was a member of the gang of 17, and I was in the budget negotiations and the group that worked together in 1987 that came up with the two-year proposal, and I know it is tough, and I know NASA is one that people are more interested in than other things. And they say oh, look, there is a nice pot of money, and I know it will be difficult. But here is what I would like to urge you to do.

You get certain windows of opportunity in life in agencies, and in Congresses. It is going to be tough this year because of budget limitations, and I could be wrong, but I sense we have an opportunity of renewed interest in, a renewed awareness that we get a lot from NASA and the space programs beyond just, you know, taking a look at Jupiter or whatever. We get a lot of benefits.

And I think that there is a little opportunity this year to maybe pick up some of the ground that we lost.

And certainly I am going to be a strong advocate in that area, and I would hope that we would get funding you need to do your job, and I think we have got a shot at this year.

Thank you, Mr. Chairman.

Senator Gore. Let me say that for the record I want to without objection include some material listing the ASRM program enhancements and some related material.

[The information follows:]

SAFETY ENHANCEMENTS (CRITICALITY I/IR)

[Net reductions]

	Failure modes	Percent	Failure causes	Percent	Failure points	Percent	Leak paths	Percent
Total reductions	39	....	423	....	1,370	....	233	....
Total additions	8	....	13	....	72	....	6	....
Net reductions	31	21	410	29	1,298	52	227	88
Case	−3	....	−40	....	−321	....	−19	....
Nozzle	−15	....	−222	....	−208	....	−173	....
Igniter	−13	....	−148	....	−769	....	−35	....
Other	0	....	0	....	0	....	0	....

ASRM PROGRAM ENHANCEMENTS

Design elimnates approximately 25 failure modes, 300 failure causes, 600 failure points, and 220 leak paths relative to RSRM.

ASRM thrust/time trace eliminates need to throttle SSME: 175 criticality 1/1R failure modes eliminated or reduced (20–30 percent reduction over RSRM).

Extensive automation of manufacturing processes: minimizes defects and maximizes reproducibility; continuous mix/cast propellant processing; potential for elimination of match cast segments; potential for significant cost reduction.

Launch processing operations reduced or eliminated: three segment motor with integrally stiffened aft segment.

Proposed design provides payload enhancements: 12,000 lbs payload improvement while increasing reliability (2400 lbs margin); advantageous for heavy payloads such as space station; anticipated reduction of ignition overpressure effect on payloads; due to multiport igniter and propellant grain design.

Personnel and environmental safety enhanced: workforce exposure to hazardous operations reduced through automation and three segment motor; public exposure reduced through water transportation; elimination of carcinogenic insulation material; hazardous waste minimized and disposal methodology improved; due to continuous mix and anticipated incineration.

Selected ASRM design provides significant safety improvements.

Joint integrity: three segment motor with welded factory joints (eliminates 5 mechanical factory joints and approximately 20 leak paths); improved hydrodynamic stability; all field joints close on pressurization; face seals rather than bore seals (inspectable until final mating); improved case material properties; verifiable bolt preload; elimination of heaters.

Igniter safety: elimination of approximately 30 leak paths; redundant face seals rather than gask-o-seals; high reliability ordinance train.

Insulation safety: joint configuration improves sealing and bond integrity; circumferential baffles; relocation of inhibiter joint.

Propellant grain—added structural safety margins.

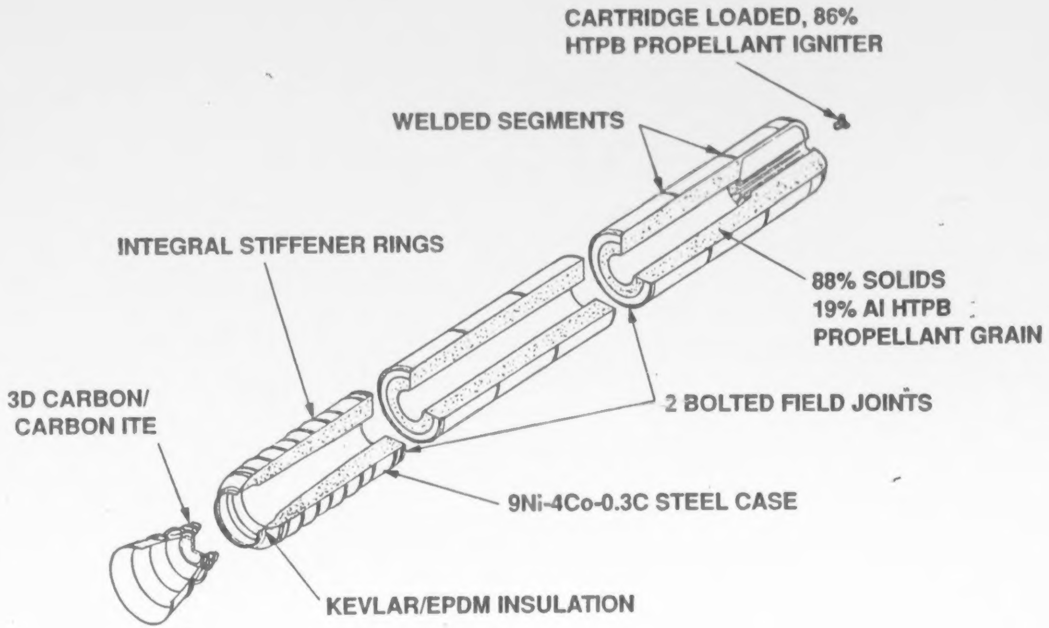
Nozzle safety: elimination of approximately 170 leak paths; elimination of 2 joints and 5 insulation parts; elimination of boot ring.

Rationale for the ASRM production facility.

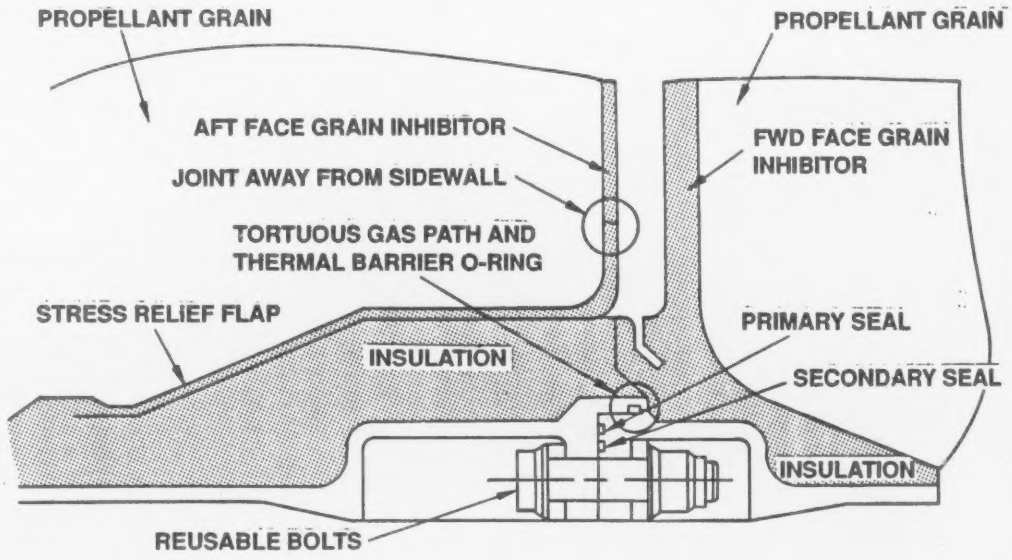
Producibility and quality enhancements; automation of currently labor intensive manufacturing; stringent process controls; reproducibility.

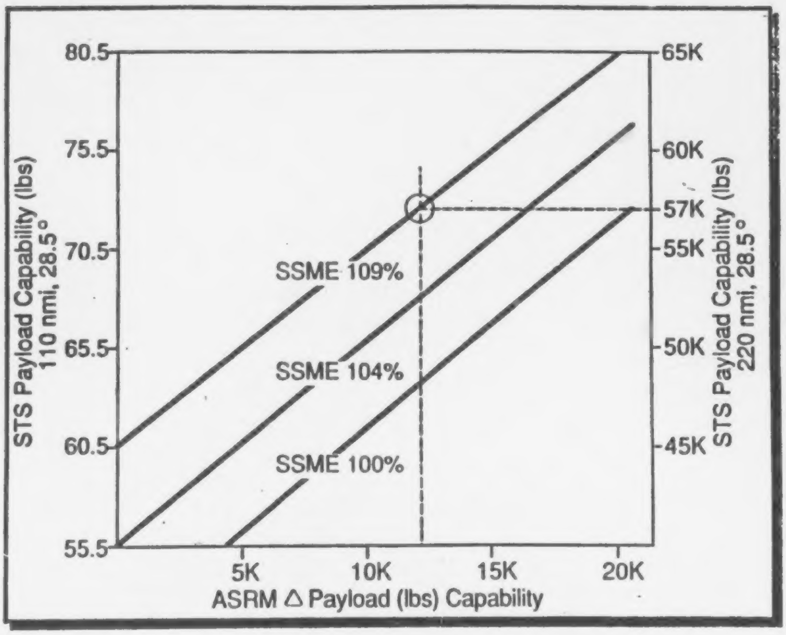
Ability to recompete contract.

ADVANCED SOLID ROCKET MOTOR


CARTRIDGE LOADED, 86%
HTPB PROPELLANT IGNITER
WELDED SEGMENTS
INTEGRAL STIFFENER RINGS
88% SOLIDS
19% Al HTPB
PROPELLANT GRAIN
3D CARBON/
CARBON ITE
2 BOLTED FIELD JOINTS
9Ni-4Co-0.3C STEEL CASE
KEVLAR/EPDM INSULATION

ASRM CASE FIELD JOINT


PROPELLANT GRAIN
PROPELLANT GRAIN
AFT FACE GRAIN INHIBITOR
FWD FACE GRAIN INHIBITOR
JOINT AWAY FROM SIDEWALL
TORTUOUS GAS PATH AND THERMAL BARRIER O-RING
STRESS RELIEF FLAP
INSULATION
PRIMARY SEAL
SECONDARY SEAL
INSULATION
REUSABLE BOLTS



STS Payload Enhancements.

Senator GORE. And we will submit other questions for the record. There are really a bunch more that we should pursue here in the open session, but I think we have had a real good discussion here today, and I again want to thank my colleagues, Senator Garn and Senator Heflin, who were here today and all of those who participated in this hearing. As members of the subcommittee, Senator Lott and I and our colleagues will do our best with this.

I would like to note for the record that we will have a markup on Tuesday on Senator Heflin's legislation that was referred to earlier, and we will submit these other questions for the record.

Thank you all for your patience and thanks for participating in this discussion today.

[Whereupon, at 12:50 p.m., the subcommittee adjourned, subject to the call of the Chair.]

[The following information was subsequently received for the record:]

Responses to Written Questions Submitted by Chrm. Gore.

Extended Duration Orbiter

Recently NASA outlined for the Committee a plan to incorporate an Extended Duration Orbiter capability into the space shuttle program. The basic intent of that plan was to evolve to a 16-day capability by late 1992 and the International Microgravity Lab Mission, and subsequently to evolve to a 28-day capability.

The NASA analysis went on to indicate that a 28-day on-orbit capability would accomplish 85 percent of all materials sciences objectives -- a significant accomplishment.

Question 1: What is the current status of the Extended Duration Orbiter program (EDO), and does NASA intend to let a private firm develop this hardware and lease it to NASA? Has NASA performed a cost analysis of this option? And, does this option require legislative authority or contingent liability legislation?

Answer 1: The EDO program is underway. NASA is going forward with design and development of the 16-day EDO system. Subcontracts are in place to procure the new Waste Collection System (WCS) and the regenerative CO2 removal system for EDO. We are also proceeding with the design and development of the cryo pallet, and integration of all the EDO subsystems. In addition to 16-day EDO efforts, planning is underway for accomplishing 28-day EDO capability. An integrated plan with requirements, schedules, and cost estimates will be available in the summer.

Because of safety considerations, NASA does not intend to let a private firm develop the initial set of baselined cryogenic EDO hardware. The prime orbiter contractor, Rockwell International (RI), will design and certify the hardware. However, we are investigating financing by a private firm and private ownership and lease of certified EDO hardware is not precluded in the future.

Current funding plans include a need for supplemental funds to maintain a 1992 EDO first flight schedule. Private financing is being considered and is shown by a generic NASA cost analysis to be in the Government's best interest under certain conditions. We have asked RI to provide a firm proposal to privately finance the funding short fall. A specific analysis will be done after receiving a firm proposal.

This option does not require any additional legislation. The EDO is an approved program and the potential liability to be incurred is small enough to be funded within the shuttle appropriation available can be funded, no contingent liability legislation is required.

Question 2: What is the proposed cost estimate and budget schedule for the EDO program? Both the 16-day EDO and the 28-day EDO?

Answer 2: The budget schedule for a 16-day EDO assuming private financing is:

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	Total
16-day	5.0	20.0	25.0	15.0	20.0	25.3	25.9	136.2
16-day Physiological		3.0	7.0	10.0	5.0			25.0
Total	5.0	23.0	32.0	25.0	25.0	25.3	25.9	161.2

The current cost estimate for the 16-day EDO is:

16-day	1.0	18.4	61.0	60.9	5.5	7.0	0.0	153.8
16-day Medical		2.4	7.0	10.0	5.0			24.4
Total	1.0	20.8	68.0	70.9	10.5	7.0	0.0	178.2

The cost of the OV-105 28-day Scar, funded from Replacement Orbiter funds, is:

		11.0	15.8					26.8

The FY 1990 budget assumes private financing of the 16-day EDO. The critical impact of this assumption is the need for approximately $36 million in FY 1990 and $46 million in FY 1991, if the Agency is to meet the USML-1 flight in FY 1992.

The complete 28-day EDO requirement is still being identified and will be complete this summer.

Question 3: Would a 16-day EDO mission require the space shuttle to utilize an automated landing system? Does the space shuttle have such an operational system, and are the astronauts willing to resort to its utilization? What would it cost to develop a reliable automated landing system? Didn't the Soviet space shuttle Buran utilize an automated landing system?

Answer 3: Current plans call for autoland capability only as a backup mode for the 16-day EDO program. The orbiter already has operational backup autoland capability. There is no concern among the astronaut community about use of autoland in backup mode as planned for the 16-day EDO after planned certification testing is complete.

Primary mode autoland capability is a possible requirement for the 28-day EDO. This issue is currently under study and an answer will be available as part of the 28-day EDO plan presented this summer. If autoland as primary mode is needed, schedule and cost associated with it will be included in the 28-day plan.

Yes, the Soviet shuttle did use an autoland capability.

Question 4: What proposed medical research and life sciences activities would need to be incorporated into the space science budget if an extended duration orbiter were to be incorporated into the space shuttle fleet?

Answer 4: The Extended Duration Orbiter medical program is a response to the requirement to extend Shuttle mission durations from a current maximum of 10 days to as long as 28 days. The extended flight times create physiological demands on the crew members that cannot be adequately assessed using current information. During the EDO program a database will be developed to define and understand the operational significance of flight-induced alterations in physiology. Procedures and countermeasures for optimizing crew performance for nominal and contingency entry, landing, and egress during extended missions will be developed and verified. Emphasis will be placed on maintaining orthostatic tolerance, exercise capacity, and sensorimotor function. Also, STS EDO environmental and monitoring requirements for air quality, water potability, surface contamination, radiation, waste management, and general habitability will require upgrading.

The extended mission opportunities that the EDO program will allow present a number of scientific benefits to life sciences research. The program provides for a more complete assessment of time dependent phenomena. Most biological processes are dynamic and time dependent, and 10-day missions only permit the study of acute phases of development, not adaptive or steady state phases. EDO also offers new windows of opportunity in areas where biological processes require 16 to 28 days to monitor, such as human bone studies, developmental biology, and seed-to-seed plant growth. Finally, the program provides for improved statistical validity, with more time available in an experiment for an increased number of sessions, an increased number of subjects, and the study of larger effects due to longer exposure to space environment, such as microgravity and radiation.

This program requires the development of specialized hardware to conduct focused investigations on Spacelab and other STS missions during the next two years. This equipment will be designed so that it can be included on manifested Spacelab missions and will not interfere with the baselined science obligation of these missions, particularly in the area of materials processing instruments. These investigations will require new ground-based programs specifically addressing the issues associated with landing the orbiter after missions longer than 7 to 8 days. In order to verify the efficacy of ground-based procedures, it will be necessary to conduct investigations on incrementally longer STS missions.

Shuttle-C

The National Space Launch Program that was recently submitted to the Congress included the following statement on the Shuttle C: "Studies to date have concluded that Shuttle-C (a Shuttle-derived heavy-lift launch vehicle) could meet potential near-term requirements for heavy lift with minimum development cost (although without the full long-term operating cost reduction, flexibility and resiliency desired). Shuttle-C studies are examining the potential for increasing the flexibility, robustness, and cost effectiveness of the Space Shuttle fleet to meet NASA unmanned launch requirements, including Space Station Freedom assembly and planetary payloads."

Question 5: Admiral Truly, is NASA still seriously considering the inclusion of funding in the FY 1991 NASA Authorization Bill for a Shuttle-C? Would the funding for this program be in lieu of ongoing activities or in lieu of proposed activities such as an additional orbiter or space shuttle structural spares?

Answer 5: At this time we are assessing Shuttle-C as a possible new start for FY 1991. If proposed, Shuttle-C funding would be a stand-alone new start. It will not be proposed in lieu of either another on-going activity, an additional orbiter, or the orbiter spares.

Question 6: How high priority is Shuttle-C? Is it higher than the Advanced Solid Rocket Motor, and if NASA could only afford one or the other, what program would it recommend -- the ASRM or the Shuttle-C?

Answer 6: The ASRM is a higher priority; it provides a generic improvement to the Shuttle system, benefiting both manned Shuttle launches as well as the potential for application with Shuttle-C.

Question 7: Based on your most recent data, what is the estimated cost of the Shuttle-C?

Answer 7: The estimated cost for the Shuttle-C is currently being intensively reviewed within NASA in preparation for the FY 1991 budget formulation process. Preliminary estimates indicate that the development and first flight cost will be in the range of $1.7--2.0 billion, in constant FY 1989 dollars.

Question 8: Does the Office of Space Flight require an unmanned heavy-lift launch vehicle to assemble the space station? Has this office performed any risk analysis to weigh the advantages of manned and unmanned vehicles for the purposes of space station assembly?

Answer 8: NASA has baselined the Shuttle for all space station delivery and assembly needs. The Shuttle can deliver and support the assembly of all station elements. If Shuttle-C was approved and made an integral part of station planning, used to the maximum extent possible, it could be used to reduce the number of launches required to assemble the space station, and could be used to place fully outfitted habitat and experiment laboratories into orbit, eliminating the need to accomplish this in space. The use of an unmanned vehicle must be sensitive to the need for manned presence to complete the assembly sequence, and for appropriate services to the unassembled pieces prior to assembly with the growing space station. Studies are continuing to examine the utilization of Shuttle-C for Space Station assembly.

A joint study was conducted by the Offices of Space Flight and Space Station to determine the advantages and disadvantages of the various manned and unmanned vehicles for station assembly. The conclusions of this study were transmitted to Congress in January 1988.

Crew Emergency Rescue Vehicle (CERV)

There appears to be a consensus that some type of crew emergency rescue vehicle is a requirement for a permanently manned space station. Recently, NASA Headquarters gave the green light to the Johnson Space Center to issue a request for proposal for the definition phase of this project with a proposed new start for the space craft in FY 1992.

Question 9: What is the current status of this program, and when will NASA release the RFP for the definition phase? Is the $7 million requested in the FY 1990 budget adequate to cover these costs?

Answer 9: The Agency has completed in-house Phase A studies of Assured Crew Return Capability concepts. An RFP has been prepared for a CERV Phase A'/B definition phase and release is expected in a few weeks. The $7 million in the FY 1990 budget, together with $4 million in FY 1988 and $11 million in FY 1989, is adequate to complete the planned definition phase contracts.

Question 10: What is the current cost estimate of a CERV?

Answer 10: The Phase A concept study defined a preliminary cost range for the CERV system with a reference cost estimate of $1.0 - 1.5 billion (FY 1988 dollars).

Question 11: Is the availability of the CERV a prerequisite for a permanently manned space station, and is a CERV now baselined in the space station program?

Answer 11: The availability of the CERV is not a prerequisite for a permanently manned space station. However, the availability of CERV at the time of a permanently manned space station could reduce the risks to the crew associated with any medical and other potential emergencies.

The CERV is not now baselined in the space station program. The Phase A' studies will determine if the CERV should be baselined as a part of the space station program.

Question 12: Are recent reports correct which indicate that the driver in the NASA decision was the fact that there is a 9% to 24% chance that one of the 8 station crew members will have to be evacuated once a year because of medical reasons? What are the odds for other events that would require the emergency evacuation of the crew members--meteor hit, loss of logistics, failure of life support systems, etc.?

Answer 12: Medical requirements are only one of several emergency scenarios possible on Space Station Freedom. Other events include interruption of NSTS flights and reasonable threats resulting in failures of Freedom systems. Based on history of similar environments (Soviet and U.S. Space Flight, Submarines, Antarctic, U.S. military pilots), NASA studies estimate a 9% to 24% risk of medical evacuation for one of the 8-man station crew over a one-year period.

Several emergency events necessitate assured crew return capability for the Space Station Freedom program. Others in addition to medical include the return or support of the space station crew during interruption of NSTS launches and to protect the crew from reasonable accidents or failures of space station systems. These latter risks are based upon history of space flights and probabilities will be further quantified during the CERV definition phase and space station design reviews. In the history of previous U.S. manned flights, two in-space system failures requiring emergency return occurred. These two incidents were Apollo 13 and Gemini 8, which occurred over a period of 460 flight days.

Transfer Orbit Stage (TOS)

On April 21, the Committee received a report from NASA on the status of the Transfer Orbit Stage -- a commercially developed upper stage that is being acquired for the launch of the Mars Observer Mission and the Advanced Communications Technology Satellite. In the report, NASA indicated that the original cost estimate of $78.6 million has escalated to $134.6 million and that the latter number is likely to grow again.

Question 13: What has led to the considerable cost increases in this program? And does NASA absorb all of these increases as a result of its agreement with Orbital Science Corporation? Should the Committee establish a cap on this program to prevent further cost increases to the government?

Answer 13: The cost increases in the TOS program have been a result of the following factors:

a) Addition of the ACTS mission integration and launch operations
b) ACTS program stretch-out from November 1990 to May 1992
c) Mars Observer (MO) launch delay from August 1990 to September 1992
d) Transfer of the MO from Shuttle to the Titan III and the integration cost for the Titan III
e) STS mandated safety changes
f) Addition of a flight RF telemetry system
g) MSFC, JSC, KSC, and LeRC program support which were not included in the original cost estimate
h) Government share of contractor's overrun
i) Establishment of program contingency reserve

NASA does not absorb all TOS program cost increases, but only a share (64 percent) of those costs that overrun the contract ceiling cost. Costs above the contract ceiling are borne solely by OSC and their contractors. NASA does not recommend establishment of a cap by the Committee, as the TOS contract already contains a cost ceiling. NASA directed changes are being stringently controlled.

Question 14: How does this procurement differ from the NASA procurement of an Inertial Upper Stage -- a so-called government upper stage -- and has that program experienced similar price increases?

Answer 14: The procurement of NASA IUS vehicles through the Air Force under OAFS government managed contracts. NASA IUS procurements have been made in conjunction with AF requirements, resulting in increased buy size with attendant unit cost reduction. The IUS program has experienced cost increases over the years; however, these increases have been spread over a larger number of production stages as opposed to the limited two unit TOS program.

Question 15: What additional mission requirements are there for a Transfer Orbit Stage within NASA? the Federal Government? or the private sector?

Answer 15: There are no know firm additional requirements for the Transfer Orbit Stage within NASA, the Federal Government, or the private sector. NASA will consider the TOS upper stage for future missions, and it is expected that Orbital Sciences Corporation will continue to offer the TOS for any compatible mission.

NASA/Air Force MOU for Launch Services

In November of last year, the Air Force indicate that they would not be able to provide a planetary backup launch of a Titan IV for NASA. In particular, this decision affected the launch operations for the Galileo and Ulysses missions both of which are now manifested for launch on the space shuttle.

Question 16: What impact did this decision by the Air Force have on the existing NASA/DOD Quid Pro Quo for launch services?

Answer 16: The decision by the Air Force not to support the planetary backup mission would be supported on a best-effort basis for a 1991 launch. The primary launch system was and remains the STS for these planetary spacecraft and the lack of the Titan backup adds risk to launch assurance.

Question 17: Does NASA still assume that Titan IVs will be available from the Department of Defense for the launch of the Comet Rendezvous and Asteroid Flyby (CRAF) and Cassini Missions, as well as for the launch of the Space Station polar platforms? What is the basis of the NASA position?

Answer 17: NASA does continue to plan to acquire Titan IV launch vehicles from the Air Force to support Polar Platform (10/96), CRAF (8/95) and Cassini (4/96)/

NASA has and continues to support the interagency DOD/NASA Space Launch Advisory Group meetings in which NASA requirements were recently reemphasized to Air Force planners. The three mentioned missions are currently included in the Air Force Titan IV manifest.

Space Shuttle Reimbursables

The current NASA FY 1990 budget request assumes that there will be no reimbursements in FY 1990 for space shuttle activities. In the out years, it assumes $50 million in reimbursable activities for commercial activities and approximately $1.2 billion for DOD activities.

Question 16: What is the basis of this estimate for DOD activities? Am I correct that since the FY 1990 budget run-out was calculated that the assumed reimbursement of $239 million in FY 1991 by DOD has been reassessed to zero? What caused this re-estimate?

Answer 16: The FY 1990 budget for space shuttle reimbursable estimates for DOD activities is based on shared secondary flights, which are less than a quarter of the payload bay. We had been budgeting for two dedicated DOD flights per year starting in FY 1992. In a commitment letter from DOD dated, January 9, 1989, they deleted the requirement of two dedicated flights per year, which would have assumed reimbursement of $239 million in FY 1991. On the present manifest, there are eight dedicated flights through FY 1991, none in FY 1992, and one in FY 1994. Since DOD is required to pay for their dedicated flights the January prior to the fiscal year they actually fly, and they have already paid for nine dedicated flights, then you are correct, they do not owe us any reimbursement in FY 1991.

Question 17: Has DOD requested any additional space shuttle launches since the Challenger accident in addition to the nine launches they already paid for? What is the projected launch rate for DOD missions in the current NASA manifest? How firm are these launches?

Answer 17: The DOD has not requested any new dedicated STS launches since the Challenger accident. They have, however, requested space for small experiments which are a part of the Air Force Research and Development activity. These will comprise approximately 0.5 STS equivalent flights over the period of FY 1993 through FY 1995.

The DOD flight rate by fiscal year, as contained in the June 1989 manifest, is enclosed. The DOD flights through FY 1991 are firm.

Advanced Launch System

Question 18: What is the current status of the ALS program?

Answer 18: ALS is currently in the 5th month of a 25 month Phase II program. It includes a mixture of technology development and system analysis efforts. Full-scale development of an ALS has not been approved.

Question 19: What is the current status of the DOD transfer of funds to NASA in FY 1990? What is the anticipated level of funds expected to be transferred?

Answer 19: The FY 1990 DOD funding level for ALS is currently being determined by the Congress. Until Congress establishes that level and the amount of funds to be transferred to NASA, an exact answer cannot be provided. The NASA estimate for funds required from DOD in FY 1990 is about $130 million, based on planning within the Joint Program Office that establishes the work to be accomplished in FY 1990.

Question 20: Am I correct that the focus of the program--especially the engine/propulsion component--has shifted from the development of new advanced technologies to improvements of existing technologies?

Answer 20: No, the focus of the technology programs remains generally unchanged; It includes both advanced technologies and improvements to current technologies. The program focus has shifted to a broader payload range which now includes payloads from 1-220 thousand pounds. Technologies associated with the flyback booster have been reduced consistent with the vehicle system study results. The managers of current expendable launch vehicles have been asked to assess the application of ALS-developed technologies to these vehicles.

Question 21: Is the ALS program likely to result in a space transportation system that delivers payloads to low-Earth-orbit for $300/per pound. (the current estimate of a Titan IV is $3600/per pound), and what is the current cost estimate of developing an ALS?

Answer 21: The $300 per pound payload launch cost was aligned with a 25 per year launch rate by the year 2005. Reductions in planning flight rates and the broadening payload range have reduced the focus on the $300 per pound cost goal. The Joint Project Office acknowledges that the $300 per pound goal is probably not achievable for current mission models.

Question 22: Finally, is the ALS program likely to use liquid rocket boosters--not solid rocket boosters? And are liquid boosters the focus of the advanced propulsion contracts NASA let in March to Aerojet, Rocketdyne and Pratt & Whitney?

Answer 22: The ALS program is still considering both liquid and solid boosters. The larger vehicles tend to be all liquid systems, whereas the smaller vehicles tend to incorporate solids. The Advanced Development Program is supporting technologies for both options. Liquid rocket engines are the focus of the Aerojet, Rocketdyne and Pratt & Whitney contracts. Five solid rocket booster definition contracts have been awarded recently.

New Space Shuttle -- OV-105

In August 1987, procurement was initiated for a replacement orbiter. To facilitate that activity, the Congress provided an appropriation for full funding of the orbiter -- $2.1 billion. Since then, this program has achieved unforeseen efficiencies and economies which has reduced the total estimated costs to $1.875 billion.

Question 23: What lessons are there to be learned from full funding of the replacement orbiter? Does this indicate that NASA and the aerospace industry can manage programs to cost if they are given the money and the necessary authority?

Answer 23: The acquisition experience for the replacement orbiter indicates that the full funding approach can provide substantial benefits when it is invoked, particularly for a well defined product like the replacement orbiter. This approach to funding eliminates the necessity for very costly rephasing of work to accommodate annual funding restrictions. It permits the contractor to manage for optimum cost savings.

Yes, advanced full funding authority and budget appropriation adds significantly to our ability to manage programs like the replacement orbiter on cost and schedule.

Question 24: Besides the funds that were transferred from the orbiter account to the space shuttle anomaly resolution and space station account in the FY 1988 appropriations bill, what additional activities have been initiated with "savings" from this program?

Answer 24: At the time the Replacement Orbiter program was announced by the White House, it was identified as a vehicle which would incorporate updated technology replacing obsolete components and improving performance and safety. Some of these enhancements are in the baseline contract such as a new Multiplexer/Demultiplexer which was obsolete and had to be redesigned, while other items were added to the contract later, as the need was identified. The latter category included such improvements as a drag chute for helping to stop the orbiter, an external heat exchanger to improve the safety of the main engines, and scarring to permit use of the vehicle for extended duration missions. These improvements are all highly desirable candidates for upgrading the orbiter fleet and their development was allowed by program savings. These improvements will be incorporated into the vehicle during its production, which is more efficient than incorporating them subsequently.

Question 25: Does NASA intend to fund fully the scarring of the new orbiter for an extended duration orbiter kit with such savings? What about the acquisition of additional structural spares in FY 1990?

Answer 25: Yes, we intend to fully fund the scarring of OV-105 to provide for the extended duration capability with the replacement orbiter reserve. In addition, we are evaluating restructuring the structural spares program if sufficient funds can be made available.

Orbital Debris

The passage quoted from the ESA report expresses a concern shared by many space scientists that the trend of increasing space debris may become a problem for space operations. ESA conducted analyses and prepared their report based on early debris data and models provided by NASA. The NSC report is the result of a more comprehensive analysis wherein the issues have been better defined, suggested approaches and their alternatives have been described, and a recommended course of action has been detailed. We hope that a copy of the NSC report is available to you for your study, but if for some reason it is not, we would be most pleased to forward a copy to you.

Question 26: Admiral Truly, how serious is the threat to the Space Shuttle and unmanned launch vehicles posed by orbital debris, and what steps are NASA and the U.S. Government taking to address this serious issue?

Answer 26: The present threat to the Shuttle and other on-orbit assets is not serious and indeed is manageable. For example, for large particles (over 10 cm in diameter) launch planning is affected by projections of the Collision Avoidance on Launch (COLA) program, which warns of potential collisions or near misses before a Shuttle launch. COLA has been used routinely to calculate and determine cutouts in the launch window so that hazards can be avoided. Typically these cutouts are one to four minutes in duration and occur twice during a launch window. In addition, the Computation of Miss Between Orbits (COMBO) program projects proximity of payloads to debris objects soon after launch, and has been used for collision avoidance.

The current environment is not a threat to ELV operations, but those operations can be significant contributors to the future environment.

The efforts that NASA is and has been engaged in are aimed at preventing man-made debris from becoming a significant hazard to future space operations.

The average time between collisions with orbital debris that might be damaging to an orbiter at 300 km altitude is 71 years of continuous on-orbit operation, based on the 1989 debris density. Assuming ten one-week missions per year for the entire orbiter fleet, this would mean that the entire fleet of orbiters would have an average expectancy of being hit to a damaging particle once in 350 years of total operation.

However, if no steps are taken to decrease the historical debris growth trend, in the year 2010 the average time between collisions will drop from 350 years to 40 years--an unacceptably low period of time.

Several actions have already been initiated to prevent this from happening. These may be grouped into four major areas:

o developing a better understanding of the nature and population density of space debris;

o minimizing debris generation by implementing operational procedures which will prevent on-orbit explosions and promote reentry of orbital objects;

o developing techniques which will increase the probability of operating within and surviving the debris movement;

o initiating technical discussions with space agencies in the international community to inform the space faring nations of our findings and to establish cooperative and mutually reinforcing activities which will contribute to the other three areas defined above.

Question 27: Are there any international initiatives under way to establish an orbital debris working group or to consider new international agreements that reduce the potential for orbital debris?

Answer 27: Since 1979, NASA has conducted technical discussions on this subject in various technical professional society conferences such as AIAA, IAF and COSPAR.

On a more formal basis, NASA has held Orbital Debris Coordination meetings with ESA and German scientists since 1986. These meetings are regularly scheduled and are for the purpose of exploring areas of potential scientific and technical cooperation. They will lay the groundwork toward potential international agreements on orbital debris prevention policies or operations.

The U.S. Interagency Group (Space) Report on Orbital Debris, which was written last year by a working group co-chaired by NASA, recognizes the importance of international discussions on orbital debris issues. It contains a section (including a classified annex) on the approach and timing for international dialogs based upon the results of the ongoing studies of the nature and scope of the debris. The report recognizes that once the U.S. reaches conclusions as to appropriate procedural or regulatory measures, the U.S. should seek ways for other capabilities to minimize the space debris including possible measures so as not to put U.S. industry at a disadvantage commercially. It also recognizes, however, that until the U.S. has reached its own conclusions, specific measures are premature and international discussions should focus on scientific and technical cooperation. Building on its already ongoing international technical discussions, NASA took the action for the Interagency Group to brief the contents of the report to the space agencies of all space-using nations and to explore areas for potential scientific and technical information exchange.

In April 1989, a NASA team briefed both the ESA Debris Working Group and a contingent of ESA member state representatives on the findings and recommendations of the Report on Orbital Debris. Both sides discussed their current understandings of the state of the debris environment and their current research projects related thereto. Several areas of potential cooperation were identified. More information will be exchanged this summer, and another meeting is planned in the fall to better define these cooperative activities. Similar discussions were held with German space officials, and NASA is very close to reaching an agreement on the sharing of some tracking data with the German technology agency.

In May 1989, a NASA team briefed the space agencies in Japan. Again, areas of potential cooperation were identified and NASA will be corresponding with the Japanese space officials about those opportunities.

Letters have been sent to the space agencies of other space-using nations asking for the opportunity to brief them on the report and to discuss areas for potential cooperation, including Canada, the Soviet Union, China, Indonesia, India, Brazil, and others. We have already briefed the director of the Indian Space Research organization when he was in Washington recently. We will arrange for similar meetings with other interested countries when we receive a response from the appropriate officials in those countries.

Question 28: Am I correct that at present the U.S. Space Command tracks more than 7,000 objects in space, objects that are 10 cm in diameter or larger and are largely found in low-Earth-orbit? Am I also correct that these 7,000 objects represent only 0.2% of the total orbital debris population?

Answer 28: You are correct that the U.S. Space Command currently tracks approximately 7,000 objects over 10 cm in diameter. Mathematical analyses and correlation of all available measured data indicate that these 7,000 objects represent only about 0.2% of the total debris population by number. However, these analyses conclude that the 7,000 objects comprise 99.97% of the total orbital debris mass on orbit.

Information about the current debris environment is extremely limited by the inability to effectively track objects smaller than 10 cm in diameter. As a consequence, there is a high degree of uncertainty in our knowledge of the current orbital debris environment and in our projections of the future environment. Other factors which contribute significantly to this uncertainty, besides that of limited measurements, are the lack of predictability in the level of future space activities and the indeterminate causes of breakup events as major debris sources. Hence, the calculations that the 7,000 objects are only 0.2% of the total population may be in great error by an order of magnitude or more.

It is important to understand that:

- Objects larger than 10 cm in diameter can produce catastrophic damage, but their population is small so as to not represent a significant threat to space operations.
- Debris in the sizes 0.01 cm to 10 cm can produce impact damage which can be serious, depending upon defensive design provisions and, because of their number, must be considered in spacecraft design.
- Debris smaller than 0.01 cm diameter cannot produce significant impact damage. However, these particles can produce surface pitting and erosion and because of their very high numbers, over a long period of time, the cumulative effect might be significant.

Question 29: Do we have an environmental problem in space as well as on the planet Earth?

Answer 29: The orbital debris situation is not currently an environmental problem. Our concern is that there might be an environmental problem of real concern by the year 2010, if efforts are not started now to better understand the current environment, the growth trends, the mechanisms which govern these trends, and procedures to decrease the accumulation of more debris in space and techniques which will provide survivability for spacecraft operations.

NASA, the DOD, and other agencies of the U.S. Government, have been engaged in efforts to better understand the real characteristics of the environment. Since most of our measurements are by Space Command radar, we have comprehensive data only on objects with radar cross sections greater than 10 cm. All of the rest of our model of the environment is based on limited data samples from optical instruments and some returned materials from the Solar Maximum repair mission. The major concern is the amount of small debris objects that have been generated by the 130 breakup events that have occurred over the past 28 years and which we cannot yet measure directly. NASA plans to build a special purpose radar that will measure the density of debris objects 1 cm or larger at 500 km altitude or less to improve our knowledge of the environment.

From the data we do have, we have been able to understand the value of a number of actions that we have taken and that have also been adopted by the ESA and NASDA. We discovered in the course of analyzing the Space Command radar data in 1978 that the upper stages that had been used to deliver spacecraft to low-Earth-orbit would, in a number of cases, explode 3-30 months after they had been used to deliver the spacecraft to orbit. When we made this determination, we adopted procedures to vent all of the residual propellants and pressurant gases. Since adoption of such procedures, we have had no further explosions of this type. ESA has adopted the same procedures for the Ariane upper stage and NASDA has applied this procedure to its H-1 launch vehicle upper stage.

NASA has had an internal orbital debris working group for several years and has worked closely with other agencies to develop coordinated studies. We expect to have even more formal and active interfaces with other agencies carrying out the actions the Space Council will direct which are responsive to the report prepared by the Interagency Group for the National Security Council.

The current threat to the Space Shuttle and unmanned launch vehicles is not yet serious but the trend, if not addressed, might be of real concern by the year 2010.

Question 30: Would NASA please take the lead in putting together a NASA/DOD/DOT working group to review the current ELV procurement policies and to come to some consensus on what constitutes a commercial procurement of launch services?

Answer 30: NASA is planning an ELV Procurement Symposium on June 19, 1989, at NASA Headquarters with the industry to hear their views and recommendations on how NASA should procure and contract for commercial ELV launch services. The objective of the symposium is to develop NASA's Small Performance Class Launch Services Request for Proposals (RFP) in accordance with industry's suggestions, insofar as possible, and develop the generic structure, content, terms, and conditions for an ensuing contract with the competitively selected contractor. In addition to the ELV commercial community, the Department of Defense, Department of Commerce, Department of Transportation, and interested congressional committee staff members will be invited. We are currently working with the Commercial Space Transportation Advisory Committee (COMSTAC) and the ELV Industry

Working Group to coordinate our activities with industry.

Question 31: Why has it been impossible to come up with a model launch services contract when it was possible to formulate a model launch service agreement on the use of federal ranges?

Answer 31: The USAF range use agreement has evolved over the past few years, as issues were raised and resolved with the ELV operators, into the current model agreement. NASA's commercial ELV use agreements have likewise evolved over the same time and through the same iterative process. The USAF has consummated four range use agreements and NASA has consummated five use agreements and six field center subagreements to date. This process has challenged the government to alter its standard way of doing business by adapting to the new commercial environment, an often difficult and controversial task. The range use agreement provides access by any/all commercial ELV operator-to-government facilities and services on a direct cost reimbursable, noninterference basis. Commercial liability is limited to the maximum probable loss of damage to physical property. The commercial ELV operator is treated as another tenant on the range.

Unlike the iterative process experienced by both NASA and the USAF during the negotiation of range use agreements, the government experience procuring commercial launch services has been quite limited. NASA's purchase of launch services to support the NOAA/GOES missions was the first time a U.S. Government agency procured services commercially. The sole-source procurement for launch services to support the Mars Observer mission is NASA's second commercial effort. Due to the circumstances and need to off-load the missions from the Space Shuttle, neither procurement was a full and open competition.

NASA's medium class ELV (MELV) request for proposal (RFP) was patterned after the GOES model, with a number of notable differences. The GOES RFP requested three firm launches and two optional services to launch virtually identical spacecraft, whereas, the MELV RFP requested three firm launches and up to twelve optional services to launch completely different spacecraft. The GOES missions utilize essentially the same orbit, whereas, the MELV missions require launch to different orbits and even from different launch sites (east and west coast). Finally, the MELV procurement is a full and open competition, allowing manufacturers with proven vehicles along with new vehicle designs to bid. Industry's concern with NASA's recent RFP has in part derived from a comparison between the negotiated GOES contract and the MELV RFP. The negotiation of commercial terms and conditions for launch services has taken place during contract negotiations, rather than through a public forum. The RFP is simply a mechanism to gather data to evaluate all bidders in a fair and equitable manner.

During the past few weeks, NASA has been working even more closely with the ELV Industry Working Group and the commercial satellite manufacturers, most notably INTELSAT, to ascertain what a standard commercial launch service contract looks like. Based on our preliminary findings, it is not apparent that a standard commercial contract exists within the commercial sector at this time. However, it is NASA's hope that the Procurement Symposium with industry scheduled for June 19, will identify and clarify what the commercial community believes should and should not be in a commercial launch services contract. NASA is confident that a consistent set of commercial launch services practices, policies, and procedures will emerge as the iterative process with industry and the Congress continues.

Question 32: What type of contingency plan does NASA have in place in case there is another catastrophic accident?

Answer 32: At the agency level, NASA has in place the NASA Safety Manual (NHB 1700.1), which defines the NASA Safety Program and provides guidelines for conducting investigations of major NASA mishaps, and NASA Management Instruction (NMI) 8621.1, which establishes NASA policy for mishap reporting and investigating. Using the Safety Manual and the NMI as guidelines, the Office of Space Flight published the National Space Transportation System Contingency Action Plan, which supersedes an older contingency document. In the event of an NSTS contingency, the plan requires immediate action to protect life and property, the prompt notification of concerned personnel, and the conduction of an investigation when necessary. Each NASA Field Center has its own contingency plan that covers general procedures and subplans that address specific contingencies.

Question 33: Does NASA have improved risk assessment techniques in place?

Answer 33: Many improvements in risk assessment capability have been made in NASA as part of the Headquarters Risk Management Program. This program develops policy and guidance, provides support to the field, and exercises oversight through independent assessment and review. On February 3, 1988, NASA Management Instruction (NMI) 8070.4, Risk Management Policy for Manned Flight Programs, was published. The NMI specifies that the capability shall exist in NASA to apply a full range of risk assessment methods, including probabilistic risk assessment (PRA). "PRA...shall be used where such methods are appropriate, as determined by the significance of the risks, the resources required...and the...(availability of) data." It is further stated that "...development of quantitative risk assessment methodology and associated data base requirements for application to future manned flight systems is a NASA objective."

Trial PRA's have been performed on major Shuttle subsystems. Such analysis can be useful for prioritizing risks as a basis for improving system safety and reliability. A Shuttle Critical Function Audit project is now underway for the main propulsion system, which will include a risk assessment capability. A PRA on the Orbiter Thermal Protection System (tiles) is in process, with special attention being directed to the management process. A quantitative assessment of Shuttle accident sequence probabilities has been performed for the Galileo mission, as part of the required nuclear risk assessment for that program. Headquarters assistance has been provided to the Space Station Program in the development of SSP 30309, Safety Analysis and Risk Assessment Requirements. A PRA on a redesigned wind tunnel at Langley Research Center will be performed as a joint exercise between Langley and Headquarters. Research is in process on enhanced hazards analysis (EHA). The EHA process uses PRA techniques to build upon the current use of failure mode on risk estimation and prioritization. We are planning a program of workshops to enhance making EHA methods a part of the day-to-day routine. Responsibilities, tools, and techniques are in final preparation.

In short, a great deal is taking place in improving risk assessment capabilities in an evolutionary and cost-effective manner, consistent with the existing NASA culture.

Responses to written questions submitted by Sen. Garn.

Question 1: At the time of last year's hearing, the House had proposed a $200 million cut in your request for Space Shuttle program. Frankly we got lucky, and were able to minimize the impact on operations largely through a $100 million transfer from the Department of Defense. But the overall budget situation, if anything, is even worse this year, and the possibility of additional DOD transfers far less likely. I have no doubt that if we decide to fund your $121 million request for ASRM, it very likely will have to be absorbed out of shuttle operations. Would you recommend proceeding with ASRM under these conditions?

Answer 1: Shuttle operations funds the ongoing launch of the Space Shuttle which is the agency's highest priority. The timely achievement of the planned launch rate in a safe manner is absolutely critical to the nations scientific and national security programs. NASA is not prepared to compromise the safety margins in Shuttle Operations. Development of the current budget submission required a difficult decision to delete some flights in order to issue safety margins within the requested FY 1990 Budget levels. Continued erosion of the flight rate for budgetary reasons would have a significant adverse impact in the nation's total space program.

The ASRM is needed to provide substantially improved safety margins and reliability for the Shuttle system, and to enhance and restore the payload performance which has been eroded by the redesign effort. As such, the ASRM is critical to the long-term success of the space program, and every effort will be made to preserve the program. A significant budget reduction would require schedule adjustments or possibly trade-offs within other areas of the NASA program.

Question 2: Last year we were forced to cut funding for the Space Shuttle Main Engine (SSME) production, test and improvement activity by $111 million, again largely because of overall budgetary constraints. In the budget before us, you are requesting an increase of $96 million, effectively restoring last year's cut. I have no statistics on this, but it certainly is my impression from discussions with many engineers familiar with the shuttle program that the SSME represents a substantially more serious concern than the RSRM, in terms of margins of safety and reliability in both its design and in manufacturing. What priority do you give to SSME improvements relative to that proposed in the ASRM program?

Answer 2: The SSME is and will continue to be a top priority in the Shuttle program. We are continuing an extensive ground test program to demonstrate margin, as well as looking at future improvements to the design and operation of the engines. The liquid engines are a more complex system that does entail more criticality 1/1R failure modes. However, to assure the safety of the entire orbiter system and the crew, all other criticality 1/1R failure scenarios must be given top priority as well. The ASRM will reduce or eliminate 175 criticality 1/1R failures by eliminating throttling of the SSME. Therefore, the ASRM will enhance SSME and system reliability.

Question 3: The Aerospace Safety Advisory Panel (ASAP) questioned the claim of superior safety and reliability flowing from the ASRM program. Although I hope to learn more on that in this hearing, I understand that one of the responses to this criticism is that the ASRM is also designed to yield a 12,000 pounds performance gain which justifies the effort on the basis of Space Station deployment concerns. Unfortunately, the program most at risk in this budgetary cycle is the Space Station. Although I am committed to do all I can to prevent termination of this critical program, should the program be killed, are there any other identified launch requirements which require the additicnal 12,000 pounds capability enhancement?

Answer 3: An industry-wide search for solid rocket motor safety enhancements following the Challenger accident was the genesis of the implementation of the Advanced Solid Rocket Motor (ASRM) program. Within the constraint of maximizing utilization of existing hardware inventories, those enhancements which were necessary and sufficient to return to safe flight with confidence were incorporated into the Redesigned Solid Rocket Motor (RSRM). The redesign, however, has by no means exhausted safety enhancements which NASA believes should be pursued for the long-term operation of the Space Shuttle. The ASRM is an excellent opportunity for making these safety enhancements. The ASRM will reduce Criticality 1 failure modes by about 20 percent; failure causes by about 25 percent; and failure points by about 30 percent. Furthermore, the new design criteria for all joints to close upon pressurization is a positive design solution and obviates the need for the use of heaters and the concern expressed in the report of the Aerospace Safety Advisory Panel relative to the necessity for a more compliant o-ring material. Notwithstanding the distinct safety enhancements for the ASRM, the reshaping of the thrust/time trace also adds measurably to the overall safety of the Shuttle by eliminating the need to throttle the Space Shuttle Main Engines during that portion of the launch when maximum dynamic pressure occurs.

In addition to flight safety and reliability, our ASRM implementation equally addresses industrial, public, and environmental safety. Automation of current labor-intensive manufacturing operations not only adds to the safety and reliability of the flight hardware but also minimizes personnel exposure to hazardous operations.

The increased performance capability provided by the ASRM remains an important consideration. We have been flying most Shuttles at maximum lift capacity and the payload demands ahead of us are even more challenging. Substantial benefits can be realized by using the ASRM, particularly for those flights related to Space Station deployment. Studies have shown that the additional performance provided by the ASRM is cost effective. The total additional lift capability provided by the ASRM will be equivalent to the payload capacity of 24 Shuttle flights over a ten-year period of operation, assuming a flight rate of 14 per year.

Question 4: Please briefly describe the proposed "private financing" of the construction of the ASRM plant. To what extent was contractor (or third party) ownership of the plant, along with lease-purchase or lease with option to purchase, considered in this procurement action?

Answer 4: Offerers were required to submit a privately financed as well as a government financed option. The privately financed arrangement, (i.e. government acquires title immediately, lease-purchase, or lease with option to purchase) was left to the discretion of the offerers. In addition, the offerers had an option to propose a privately owned plant. No private ownership options were submitted.

The proposal chosen was the private financing arrangement proposed by Lockheed. In this proposal, NASA will immediately take title to the ASRM facility. The private financing of the ASRM plant will be a variable interest loan, and the rate will be readjusted every six months. Borrowing only will occur when funds are needed. The full cost of the project will not be borrowed up front.

Question 5: I should take a moment to note that my concerns over the ASRM program are NOT motivated by a parochial concern over defending Thiokol. In fact, I understand that Thiokol is a major subcontractor in the successful bidding team and stands to gain about a quarter of the ASRM development contract value. It is unavoidable, however, to compare their activities under the existing RSRM contract with that proposed in ASRM if only because they will likely continue building motors for the next ten years regardless of our decisions on ASRM. The Thiokol plant is contractor owned, and I understand that in recognition of possible improvements and efficiencies yielded in the manufacturing process, they have proposed to invest about $150 million of their own money to upgrade their plant, and to amortize the cost of these improvements within the existing price of motors being charged the Government.

Why should the Government spend in excess of $500 million to build its own separate plant (including equipment), if there is a privately owned plant which can, and will be upgraded, at no additional cost to the taxpayers?

Answer 5: NASA and Morton Thiokol Inc., (MTI) Wasatch Division have entered discussions on modernization of the Wasatch facility. The discussion centers around the upgrade of their facility at an estimated cost of $250-300 million. Morton Thiokol Inc. would finance the improvements and recover their investment through cost savings incurred on the block 3 buy of the RSRM. This plan is in the preliminary stages and the details have not been finalized. In addition, this plan has not been presented to or approved by the Morton Board of Directors, or NASA top officials. Accordingly, in the absence of a firm commitment, the likelihood of an upgrade remains hypothetical. Although this option may prove attractive in the future, it will not provide the performance benefits projected for the ASRM. Furthermore, Congressional direction following the Challenger accident urged NASA to instill competition into the SRM program. A government facility will give NASA the latitude to change contractors, should the need arise.

Question 6: To what extent will the Congress have to provide additional legislative authority to permit NASA to enter into the proposed "private financing" contractual arrangement (in terms of termination liability).

Answer 6: NASA will need legislative authority to assume contingent liability to protect the contractor's investment in the event the ASRM program is terminated for convenience before the cost of the plant and its equipment has been amortized. This authority is needed because it is a violation of the Anti-Deficiency Act to insure even a contingent liability above the level of available appropriations. The authority to incur this contingent liability is preferable to obtaining actual appropriations to cover the liability because the long-term nature of the space program makes it highly unlikely that the contingency will occur. Thus, making funds available to fund the contingent liability would exacerbate this year's budget problems by requiring the appropriations of funds that will, in all probability never be expended. Instead, the contingent liability will be amortized by expenditure of funds appropriated for the purchase of ASRM's.

Question 7: The Aerospace Safety Advisory Panel report recommended that "NASA reexamine the plan to procure the ASRM and study other options for the replacement of the current solid rocket motors...(including) liquid rocket motors." What is the current status of NASA actions with respect to this recommendation?

Answer 7: NASA had considerable discussion of this issue prior to the Advanced Solid Rocket Motor program decision. The decision was made as a result of safety, technical, and programmatic considerations. NASA plans to continue with the ASRM. (Attached is a memo sent to Mr. Joseph F. Sutter, Chairman of the ASAP, stating NASA's position)

Shuttle-C

Question 8: As you know, I am a strong advocate of the Shuttle-C. Rather than yielding a modest increase in what individual orbiters can carry within the constraints of a small shuttle fleet, the Shuttle-C would more than double our payload capability and is not dependent on the availability and processing constraints of the orbiters. And it would more efficiently utilize existing production capability for external tanks and booster motors. Do you agree with my analysis of the merit of the Shuttle-C program?

Answer 8: If approved, Shuttle-C could deliver approximately 100-150 thousand pounds to orbit depending on whether two or three main engines are used. The Shuttle-C concept has an unmanned cargo element in place of the Shuttle orbiter, and a new processing facility would be required for this cargo element. The cargo element design allows for use of existing and planned NSTS payload processing capabilities. The Shuttle-C could use the same production capability for external tanks and booster motors as the NSTS. However, we envision flying Shuttle-C an average of only about three times per year, with an associated reduction in the number of Shuttle flights. Hence, there should be no significant difference in external tank and booster production efficiencies.

Question 9: What is the current status of Shuttle-C development work?

Answer 9: Three parallels systems definition contracts were begun in FY 1987, to define a Shuttle-Derived Vehicle configuration most appropriate to satisfy the anticipated national needs beginning in the mid-1990's. The current Shuttle-C concept was a result of these studies. These contracts have been extended through the end of FY 1989 and, along with in-house efforts, are further defining the Shuttle-C configuration. FY 1990 funds will be needed to continue the activity to mature the Shuttle-C system design in preparation for a potential new start proposal in FY 1991.

Question 10: It is very impressive to see the table displaying "safety enhancements, net reductions of criticality 1/1R" in terms of a 21 percent reduction in failure modes, a 29 percent reduction in failure causes, 52 percent for failure points and 88% for leak paths. While I am glad to see that spending a billion dollars can yield improvements in design, it is unclear to me whether this means that a percent reduction in the number of failure modes, causes, points, and leak paths equates to the same percent reduction in risk of failure. Am I correct in that simply reducing the number of failure modes does not automatically reduce the probability of a failure?

Answer 10: Reducing the number of failure modes, causes, and points should reduce the probability of a failure. While this does not equate to a one for one percent reduction, the ASRM is an excellent opportunity for making significant safety improvements. The new design criteria is for all joints to close upon pressurization. This in itself is a positive design solution rather than a fix. Notwithstanding the distinct safety enhancements for the ASRM, the reshaping of the thrust/time trace also adds measurably to the overall safety of the Shuttle.

Question 11: To what extent can the design improvements proposed for the ASRM be incorporated into the RSRM?

Answer 11: We are presently evaluating, and will continue to evaluate, suggested improvements to the RSRM and plan to pursue those which promise a significant benefit to mission safety. However, to incorporate the design improvements into the current motor would require a new case design, as well as major modifications to MTI's facility. While it may be possible to incorporate the new automated manufacturing improvements, it should be recognized that this would entail downtime of the current production facility.

NASA AUTHORIZATION

WEDNESDAY, MAY 17, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met at 9:40 a.m., in room SH-216 of the Hart Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The subcommittee will come to order. I would like to apologize to our witnesses and guests for the delay in starting. A lot of committees and subcommittees for some reason chose 9:30 on Wednesday as the time to start their meetings. Also various markups were in place and full Committee Chairmen have a way of liking quorums so they can do their business That is the reason for the delay in our hearing this morning and I do apologize. I also appreciate your patience.

We are going to receive testimony today from NASA and from the Department of Transportation's Office of Commercial Space Transportation about the status of their respective space commercialization programs. The subcommittee is very interested in this subject and very interested in the way it has been pursued over the course of the last eight years.

This subcommittee and the Congress as a whole have spent a considerable amount of time discussing space commercialization, but thus far we actually have very little to show for it. This year we had our first successful domestic ELV launch under the DOT Licensing regime, but at the same time we find our share of the world launch services market eroding at a very rapid rate and visible concern about the survivability of the U.S. launch industry at all in the marketplace of tomorrow.

Last week the National Space Council strongly endorsed the LANDSAT program but admitted that privatization of this system was a premature concept. Until the turn of the century it is clear that funding for the program would be a Federal requirement. The only problem is, where does that money come from? If we pretend that it is going to be privately funded when objective observers really know that that is a myth, then we end up lying to ourselves and hurting ourselves in the process.

In any event, after hours of meetings, discussions and debate, the Administration has submitted its final appraisal of the proposal to develop a commercially developed space facility. It turns out that concept was premature, too, and there is more spadework to be done before there are Federal requirements for such a system. Again, we have to avoid pretense and avoid the prospect of ideological yearnings overtaking a clear appreciation for what we refer to as reality.

Maybe part of the problem with the space commercialization program has been that it was driven by ideology and budget gimmickry and not by pragmatic assessments of reality. Maybe another part of the problem was the emphasis placed on the policy proclamation and not on the implementation plan.

In any event, whatever have been the transgressions and mistakes of the past the message is quite simple for those of us who deal with space issues today. We need to decide what we are going to do and then get going, because the competition is not similarly deluding itself, lying to itself, pretending things exist when they really do not and they are not waiting for us to resolve the debate in the United States. They are just going right ahead and threatening to leave us behind.

As was so eloquently noted in the report of the Business High Education forum entitled, "Space—America's New Competitive Frontier" and I am quoting: "foreign countries have targeted and are winning major world market shares in the rapidly growing, high technology and service industries largely because the United States is failing to utilize its competitive strengths. It is ironic that the nation that has made the greatest contribution of space technology to the world should now be in danger of losing that lead as well."

Today I hope to explore with Jim Rose of NASA and Stephanie Lee-Miller of DOT and other witnesses, what plan of action they have to meet this challenge and to position U.S. industries to compete in tomorrow's markets. I also hope to explore the current thinking in the Bush Administration toward space commercialization.

For the past eight years we have been dealing with an abstract concept—space commercialization—whose definition seems to change on an annual basis. But today that concept is starting to be defined in a new and measurable way—market share, new jobs, new services and products, new firms. So it is now up to the Congress and the Administration to work with these firms and industries to determine what our role is in the commercialization of space and to provide the support required to guarantee a competitive commercial space industry.

I must admit that I look forward to today's discussion and hope that we can walk out of this room at the end of the hearing with a little bit better appreciation for what space commercialization is and what needs to be done to make sure that space does not go in the same direction as consumer electronics, textiles and other apparently declining U.S. industries.

I want to recognize my colleague, Senator Kasten for any opening statement he might have.

OPENING STATEMENT BY SENATOR KASTEN

Senator **Kasten**. Mr. Chairman, thank you. I too look forward to our hearing this morning on the fiscal year 1990 budget for NASA's Office of Commercial Programs and related NASA and DOT programs.

As you point out, Mr. Chairman, the commercialization of space presents so many exciting possibilities. The programs that we are going to hear about today are to assist the private sector in commercializing space. $38.3 million is requested for these programs.

I am also aware of the Space Phoenix program which will utilize initially five external tanks jettisoned by the space shuttles before entry. NASA signed a memorandum of agreement with the University Corporation for Atmospheric Research in December of 1988 and no taxpayer dollars will be used in this program.

Working with the aerospace industry, the Federal Government and the financial community, UCAR will develop these external tanks into facilities for use in space to the degree required by scientific, commercial and government users. The University of Wisconsin is a member of UCAR and I am excited by the prospect of such commercialization efforts in addition to the other ones that we are going to be hearing about today.

Mr. Chairman, thank you. I look forward to the testimony.

Senator **Gore**. Well, thank you very much. Mr. Rose, you are our first witness—James T. Rose, Assistant Administrator for the Office of Commercial Programs at NASA. I would like to welcome you and indicate that we really have a good deal of interest in the issues you are going to discuss and let me note for the record that Mr. Rose was formerly the head of the McDonnell Douglas electrophoresis program which was one of the first attempts to do commercial processing in space. I assume, therefore, that when you discuss these issues with the subcommittee today that you will bring not only your official views but also your personal experiences into that discussion and we look forward to that.

Your prepared statement will be included in full in the record, but before proceeding with your presentation, could you introduce your colleagues at the table?

STATEMENT OF JAMES T. ROSE, ASSISTANT ADMINISTRATOR FOR THE OFFICE OF COMMERCIAL PROGRAMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY EDWARD FRANKEL, GENERAL COUNSEL; AND WILLIAM McGARVEY, ASSISTANT ASSOCIATE ADMINISTRATOR FOR FACILITIES MANAGEMENT

Mr. **Rose**. Senator, my colleagues—I am well supported here today for questions that will come up, from Mr. Ed Frankel on my left, who is the General Counsel of NASA, and from Billy McGarvey, who is the Assistant Associate Administrator for Facilities Management for NASA and so they are here to assist in their specific—because we expect we will get some questions in which they response will be vital.

Senator **Gore**. Very good. Please proceed.

Mr. **Rose**. I am pleased to be here. This is really my first time, being fairly new to the job—a little over a year—to represent the

Office of Commercial Programs, but I would like to state that our office is the focal point within NASA for the commercial development activities of space, the technology transfer programs which deal with taking space technology and transferring it into the private sector and also the small business innovation research activities within NASA which is beginning, and I think all three of these are quite critical to the whole issue of international competitiveness. In fact, I feel that my job is perhaps maybe one of the more important jobs in the agency under the climate that we are now dealing in.

I want to spend most of my time discussing the commercial development of the space program and I think that is where the interest lies today, and there is no question that not only in this country but abroad, specifically abroad, there is a real recognition there that space does harbor a resource for exploitation commercially and that if U.S. industry is going to compete with foreign competition, who is either directly subsidized by the government or indirectly subsidized by the government in the way they do high technology development, we in this country, we must find cooperative ways to deal with this issue between our own government and our own industries if we are going to compete.

Now, achieving the type of cooperation necessary, we do—based on historical roles that have been played between government, industry and academia, we have got to overcome a few obstacles—the adversarial relationships that have developed over the years between government and industry; the sharp division between government research and commercial development caused by research-driven, rather than market-driven approaches to technology innovation and of course the high cost of space, to get into space and that is where the arrangements that the Europeans and the Japanese have is much different than ours, but we are taking steps.

It is the job of my office to try to get the fullest involvement of the private sector into our space programs on a commercial basis. I have taken on another job. I want the U.S. industry to take the lion's share of what is developed commercially from the space environment. In the last year we have put together a strategy and the necessary mechanisms and infrastructures we hope to carry out such a strategy and that is what I want to discuss with you today.

First, I am going to use just a few charts I hope that you have in front of you. If you can look at Chart No. 1, its title is "Spectrum for Privatization and Commercialization Activities. 'What is important about this chart—and we ought to try to understand what is commercial space? What are the areas we are dealing in, and if we can categorize them, because their maturity and their needs of cooperation between government and industry are going to be quite different.

We have chosen to categorize them into four major categories. What I call information systems, which is communications satellites, remote sensing, navigation issues. Basically the communications satellite business is a mature business. However, there is still confusion as to who does the research. Our remote sensing you mentioned it earlier, LANDSAT is in trouble. One of the main reasons is we have not at this point developed adequately the private market in that industry. We are taking major steps to do that now.

Senator **Gore**. Well, that should not be privatized, should it? Well, go ahead. I will come back.

Mr. **Rose**. Transportation is another category. Obviously the expendable launch vehicles including sounding rockets, all the way up to systems that can put hundreds of thousands of pounds in orbit have been proposed. There are some 15 companies, entrepreneurial companies offering services in this particular field. Unfortunately, most of them right now depend upon the government or are looking to the government as being a customer.

The field of infrastructure. We call infrastructure those things like carriers that can carry payloads such as Space Air. The CDFS would be a piece of infrastructure. Privately developed systems for processing materials, or privately developed upper stages. We put these in a category we call infrastructure. There are some 13 companies out trying to develop certain aspects of infrastructure at the present moment. Again, they are all looking to the government to be the customer.

The area of new products and services, which is the area where we hold out great hope for future development of new pharmaceuticals, crystals, other types of services. This is an embryonic industry at this particular point in time. In fact, it is just in the technology development stages and we can look to 5 to 10 years before something might occur in this particular arena. The problem with this industry is getting the technology developed.

I have another category I call full commercialization. It is important to understand what is full commercialization? Our definition of it is, private markets in all technological fields supported by private developed infrastructure and transportation.

Understand this: we need to get industry involved in the planning. We need to get strategic plans developed and we also need to have implementation plans and these we are working on at the present moment.

What is coming out of this is a strategy and I think it is important to try to understand where we are coming from. What is given in our strategy is that private markets and products must be developed. If true commercial development is to happen we have got to have private markets and products. The information systems area on Chart No. 1 and the new products and services area on Chart No. 1 are those areas where new products will emerge and in turn they will stimulate the growth of the private sector.

Now, the private markets from those two areas will be the future customers of the infrastructure and the transportation market. Therefore, our strategy is to support and to get industry directly involved in planning and overseeing the nation's commercial space activities.

Second, the government must concentrate its assistance and resources on stimulating the new market development and the government should support those transportation and infrastructure ventures that can directly contribute to developing new markets or be transitioned in the future from government to private use.

So with that strategy we have set out to implement it and I will give you just a few examples of that implementation. Number one, getting the private sector involved in our space planning.

Through the AIAA we engaged industry, some 90 persons who are very experienced people, from many different companies to work with us in establishing goals and objectives up to the year 2020 in which we could begin to measure commercial progress.

In other words, if we could establish goals for where we would like to be in the communications field by the year 2025, we could better establish what are the things we need to be doing in 1989, 1990.

That report from this Committee is coming out this month and it is going to give us the type of information that we feel we need to help us complete a strategic plan.

Second, we have established a standing committee called the Committee to Support the Commercial Programs Office. That is made up of 18 CEO level executives and also heads of universities. Joe Wyatt, the head of Vanderbilt, serves on this Committee.

But this Committee is there to help us define the proper roles of government and industry in each one of these four areas of commercial space and it is also there to help us oversee the implementation of some of their recommendations.

Their recommendations are coming forward in a formal report that is scheduled to be released the 25th of this month. Mr. Ed Donnolly, the ex-Chairman of Air Products Corporation, who heads the Committee, is presenting the recommendations to the NASA Advisory Committee today in Houston, Texas, so we are very close to having the recommendations of this Committee, which incidentally has met four times in the past nine months so we are getting very good involvement of CEO-level personnel in with our planning process at the present moment.

Next, I would like to talk about developing the new products field. We have two major initiatives going to help establish new markets and especially I am going to concentrate my efforts on those that require strong government support because of the length of time to develop—microgravity or medical type products that derive either from microgravity or from high vacuum.

We have a joint endeavor program. The joint endeavor program is a cooperative program between industries and government. If those industries have reached the place they are ready to invest in their own technology, in their own development process of something they have in mind that could become an application, then NASA will work with them to provide them the services and the flight time to test the technologies in space. So this is a way of providing incentive to industry to look at space as an avenue for developing new products and new services.

We currently have five active joint endeavor partners, including the 3M Corporation, Boeing, Rockwell, the ITA Corporation, which is a small business, and one other. What is more encouraging, we have nine—or, eight new companies we are negotiating with on joint endeavor programs.

One is the Union Oil of California, who is looking at a proprietary sensor they have developed for looking at oil reserves which they would like to test in space and then obviously engage a satellite system to put them in orbit and to actually use this as part of their business base.

We are very encouraged. Corabe is another company that wants to provide a service, a telemedical service between the ground and the experts on the ground and what goes on in the space station. It is an infrastructural service. We have an agreement with them to develop this capability and they are doing it on their funds and with our support.

So these are the types of programs we are getting into. These eight new companies, none of them are aerospace companies, which again is encouraging. Probably the initiative that I want to really highlight today to you is the initiative we call the Centers for the Commercial Development of Space.

These centers which we have created, some 16 of them and they are listed on Chart No. 2, they are consortia of university, industry and government working together in seven specific technological fields to look at space as a place to develop new applications.

Now, what is unique about them is that the research being done in these centers is being driven by their industrial partners. Therefore, if something is determined that has technological merit, industry is sitting right there to pick it up and to move it forward and so we believe this is the proper way to begin to engage on a large scale industry participation and looking at space as an avenue to develop new products and new applications.

Are the CCDS's working? We believe so. Chart No. 3 would indicate to you that these 16 centers have now, we have the support of 48 different universities in selected technological fields. Supporting those 16 centers, Chart No. 4 would indicate we have 128 companies now actively engaged with these particular centers and again, Mr. Chairman, two of these centers are in Tennessee.

Senator GORE. I was noting the progress in this program.

Mr. ROSE. But, I think the next chart—Chart No. 5 would indicate to you the degree of involvement that we are near getting.

What I have got listed here are the JEA, or Joint Endeavor Partners on the first group—that is the 3M, the ITA, Boeing and Rockwell elements. Below them are the 16 CCDS Centers.

And what you see across in years are the payload flights that have now been defined. These centers and CCDS's have defined some 80 payloads—where each one of these payloads can lead to one or a multiple number of products if they mature, and as they develop.

What you see is that in 1988 the 3M Corporation and the University of Alabama, Birmingham, had two flights flown with their particular payloads.

In 1980 we are going to have—in 1989, we are having 14 flights from that perspective situation.

What I am showing you is the fact that we have a very active program now with commitments from the CCDS's and the industry partners to develop the necessary payloads that will go into space, and prove yes or no on certain potential technologies that could lead to applications.

In total we have about 249 flights identified across the years. What I will also note is that the bottom group have come, have just spent a little over a year. We expect their requirements to grow in the out years—in the 1993 and 1994.

We expect that we will not see the tailoff that is there. It is going to continue to expand and grow.

You can see that on the right-hand side—the number of industries that are affiliated with these particular centers. There are some 144 industries involved. I said 128 earlier. Some industries are working with more than one center in different technologies. And between other government agencies or universities, there is the 58 number of involvement there. And I showed you that the universities make up 48 of that particular group.

So we believe we have established a large involvement of industry that will lead to the types of products that we hope to develop.

The page number six would give you an idea of what has happened most currently and through this year—we expect to happen. As you can see in the September flight, which was the first flight after Challenger, that the shuttle went up; to the University of Alabama, Birmingham, we had payloads aboard that represented the Burroughs Wellcome Company, Dupont, Merck, Sharp and Dohme, Schering-Plough and Upjohn.

In March we had those following companies which included Eastman Kodak, Lilly, Dupont again, Merck, Shering-Plough, Smith, Kline and French.

This one payload developing protein crystals, could very well lead to as many as 10 or 12 new pharmaceutical products of the future. So one payload, sometimes, represents a fairly large number of industries and involvements.

Even as I speak, things are changing. The bottom of your page—on page six, the Battelle/Amoco flight on STS-32, they are going to give way to a flight right after the first of the year so that the Alabama, University of Alabama at Birmingham protein system can go aboard the November flight. And we actually are going to fly two different payloads for UAB in that particular flight.

So we do have an aggressive program to develop the markets I was speaking of. Now that the ingredients of an industry include products and markets, they include infrastructure; they include transportation. Now we are beginning to couple—now that we have got an aggressive, active activity going to develop the markets. Now we are beginning to couple those with the infrastructural companies and the transportation companies.

In your opening remarks you mentioned the flight of the totally private venture—that is one of our CCDS's. That is the University of Alabama, Huntsville.

What we did, and chart number seven speaks to it, they wanted to fly a sounding rocket, because it would give us early information about certain key technologies relating to microgravity products.

I said, "Go get you a private concern to fly you, and we will use the grant program which we have to make sure that you have the necessary resources to cover that." They engaged—they went out and wrote an RFP, Request For Proposal, developed it, put it on the street, had four companies bid, made a selection—the whole process was done in nine months. It was efficient; it was effective, and it was commercial.

We had six major payloads fly on that flight—all of them developed by the private sector. They were all—everything worked.

Every payload performed well and the science from it is considered outstanding.

This was totally done privately in a 9-month time frame, and I believe it is a role model for what we plan to do in the future in bringing more of the market development activities—tying them in with the infrastructural activities.

As far as the future, we have just—the University of Alabama, Huntsville, has just expanded the program. We will have up to two flights a year with two different systems that will be provided by the transporation industry.

Our center at Huntsville—at Houston, Texas—the University of Houston Center, which is doing some very important work in epitaxial growth technology which requires very high vacuum—requires a weight shield.

We are allowing the SII Corporation—they are colloborating with another infrastructural company to produce commercially a weight shield to help them provide that type of technological support. And we know for a fact that the price will be—at least we estimate a sixth of what it would be if we had tried to develop it ourself. Plus, there will be at least a year improvement in schedule time, in order to provide that.

But, here is a method of letting the private sector begin to decide what they need. Let the markets begin to drive what we need in infrastructure—what we need in transportation. We will give them the mechanisms in which to make that happen. And I think this is the strategy that we will continue to develop over the coming years of engaging—now that we have adequate market activities developing.

And remember when I say, "market activities developing," these are people developing the technologies to make markets, which is what we do not have today.

The infrastructural world and the transportation world can support that now, and will begin to develop the requirements of what is needed as these industries mature.

If you take the biomedical portion—we have three CCDS Centers working in the biomedical field. There is some 41 major corporations of companies in that field working with these centers. Some of those companies are going to be successful.

We have just had the entry of Genentech, which is the most prestigious genetic engineering company in the world, who have made a major commitment to look at space as an avenue to do new and better things. And so that has happened in the last three weeks.

So we are greatly encouraged that we have a strategy—that we are beginning to develop the markets. We are tying the markets into the infrastructural companies. And through this mechanism we are going to let the industries decide what needs to be done.

We supported the way we can support it best by giving it some grant support, where needed, by providing our facilities and our knowhow to get things built to go into space and providing this necessary space transportations in the early stages to make it happen.

So we are off and running, and I have made my say, and I am sure I have probably spent too much time elaborating. But, we are encouraged and we are looking to the future that we do have a strategy. We have a way to go, and we know where we want to go.

[The statements follow:]

Statement of

James T. Rose
Assistant Administrator
Office of Commercial Programs
National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

Every American is a shareholder in our country's civil space program. Each citizen has contributed to our national investment in space, an investment which, according to a variety of economic studies, has produced a high yield return to our Nation's economy.

It is widely recognized that our space endeavors have provided an impetus for technology development that has improved our lives on Earth while stimulating economic growth. Space technology has enabled the emergence of new and improved products and services for everyday living in such fields as health care, public safety, environmental protection, energy, transportation, and industrial manufacturing, to name just a few.

There is increasing recognition, both here and abroad, that space itself harbors valuable resources that represent a new economic frontier for the space-faring nations of the world. We are at the point where commercial development of space is both a logical next step and a prudent competitive strategy.

The space program, therefore, is making a significant contribution to this Nation's ability to compete in the global marketplace, a contribution that we are working to expand through our cooperative efforts with U.S. industry.

Mr. Chairman, you and the members of this Subcommittee, and many other members of the Congress, are well aware of the economic potential of space. And, because of this, you have assigned NASA the important mission of encouraging the commercial use of space, and stimulating expanded investment and involvement by the U.S. private sector in our Nation's civil space program. NASA's Office of Commercial Programs (OCP), which I head, provides a focus within the agency both for programs supporting the commercial application of existing space technology and the commercial development of space itself.

I am pleased to have this opportunity to discuss with you today these two important programs, and I will begin with a description of our efforts to encourage and support the commercial development of space.

COMMERCIAL DEVELOPMENT OF SPACE

In 1984, the Congress amended the Space Act, directing NASA to "...seek and encourage, to the maximum extent possible, the fullest commercial use of space."

Over the past year, we have worked hard to approach commercial development in a comprehensive way, recognizing both the broad picture and its component parts as we define an overall program to reap the fullest economic benefits from our civil space program. We have categorized and scoped the different types of commercial space activities, assessed the unique requirements and issues affecting growth of each, and developed mechanisms and infrastructures to carry out a comprehensive and aggressive program.

Commercial space activities can be grouped into four general areas: space transportation; information services such as communications, navigation, and remote sensing; new products and services, such as those associated with materials processing in space; and, privately provided space infrastructure.

There are a number of things that government can do to improve the climate and prospects for greater commercial involvement in space. Today, I will be outlining a number of steps that NASA is taking to encourage more fully the resources and talents of the private sector in commercial space endeavors.

a. New Market Development. The issue of commercially developed and privately financed space infrastructure has received a great deal of visibility lately because of its immediacy. NASA is at work refining the criteria and guidelines used for evaluation of infrastructure proposals coming to us from outside the agency, as well as further infrastructure projects within NASA that could be candidates for private sector development. This is and will remain an iterative process involving NASA and industry. Establishing appropriate criteria and developing appropriate processes will be necessary to increase NASA's planning capability and to heighten the potential success of the proposed ventures. In addition to performing the initial screening of infrastructure proposals, OCP will continue to be an advocate for the private sector throughout the entire evaluation process.

Although, initially, the U.S. Government may be a predominate user of new goods and services, ultimately, new markets must be developed beyond the U.S. Government. This is a quite different aspect of commercial space which involves the development of new technology by the private sector leading to the provision of new goods and services for commercial markets. These are private sector embryonic product development programs that we expect would require a development period of 5 or more years. But, these are also the activities which hold the greatest potential for economic payoffs to the Nation's economy; therefore, it is vitally important that the government provide the appropriate long-term commitment.

Information services and new products and services will stimulate the growth of private markets and set the pace for commercialization. The other two types of activities, transportation and infrastructure, provide the necessary support and services required for new market success. New market development areas are the future customers for transportation and infrastructure enterprises.

Therefore, the government must concentrate its assistance and resources on those ventures that can contribute to development of markets for new products, or can be transitioned into the private sector. We believe that we have developed a program with the right balance of thrusts to encourage each of the commercial space areas in a manner appropriate to its unique characteristics and stage of development.

b. OCP Accomplishments. Let me highlight some of the more important OCP accomplishments that have taken place over the past year:

(1) We have identified areas of our organization where skills and talents needed to be augmented, due either to departure of personnel or changing needs and requirements. We have been successful in bringing on board people to meet these requirements, and we have shifted some organizational responsibilities in order to meet changing requirements.

(2) Recognizing that we now have a need to address financial implications of the ever increasing commercial projects and proposals, we have put in place a structure to accomplish this. In developing this capability, we are drawing on the skills of both our government employee staff and a number of private sector experts from the business and financial communities.

(3) We have established the Commercial Programs Advisory Committee (CPAC) to help determine a national course for commercial development.

(4) We have neared completion of a long-range strategic plan with private sector assistance.

(5) An Operations Management Council for the Centers for the Commercial Development of Space (CCDS) to improve their effectiveness has been established.

(6) We have developed a flight plan to maximize transportation opportunities for CCDS payloads and Joint Endeavor Agreement (JEA) partners.

(7) We have drafted a Commercial Space Infrastructure Policy, Criteria, and Procedures document for evaluating industry proposals.

(8) Six new NASA/industry agreements have been signed, including the first for the commercial use of Shuttle external tanks.

(9) Eight potential new JEA partners have been identified.

At this time, I would like to discuss some of our accomplishments in greater detail:

c. Involving the Private Sector in the Planning Process. As independent national economies merge into an integrated global economy, government policies and industry practices can no longer operate in the "splendid isolation" which has been our tradition. There are those who contend that since space will always be there, there is no reason to hurry the development of commercial applications. When there is anything worthwhile to commercialize, industry will do it. Therefore, government should stay out of the way.

In the face of foreign competition, the pace for developing commercial space applications by the private sector in the United States does matter. For U.S. industry to compete against foreign firms receiving direct or indirect government support, appropriate cooperation between the public and private sectors in this country is essential.

There is no question that commercial developments in space will be done by the private sector; therefore, the private sector must be involved in defining what needs to be done to stimulate their involvement. My office has taken two major actions to bring industry's views into focus:

(1) Commercial Programs Advisory Committee (CPAC). First, we asked 18 Chief Executive Officers and university presidents to join us in forming CPAC. CPAC is represented by large and small firms from many industries, including aerospace, nonaerospace, and financing, and offers a diverse and wide-ranging perspective. Mr. Edward Donley, Chairman, Executive Committee,

Air Products and Chemicals, Incorporated, is the CPAC Chairman. CPAC is a standing committee of the NASA Advisory Council which will provide NASA with continuing advice on the proper roles and responsibilities of government and industry in commercial development of space.

For this Subcommittee to appropriately guide NASA and the Nation in our commercial development effort, they must be familiar with all segments of the industry. NASA has expended considerable effort to provide CPAC with the background information they need for their informed participation. We used professionally produced video tapes to condense over 200 hours of interviews with 64 commercial space experts into 5 hours of informative discussion of the issues.

(2) Strategic Planning. Second, we contracted with the American Institute of Aeronautics and Astronautics (AIAA) to conduct a study of issues and potential objectives associated with commercial development of space. AIAA formed a steering committee consisting of senior level, private sector managers with considerable experience in the commercial space environment. The AIAA work represents inputs of over 90 industry representatives in 7 working groups, and will assist CPAC in articulating industry concerns and proposing recommendations for NASA and the Nation. The CPAC report and recommendations for national consideration is expected to be released during June 1989. The recommendations can then be incorporated into NASA's comprehensive strategic plan for encouraging commercial development of space.

d. Supporting the Development of New Products and Services. The development of new products and services, especially those involving materials processing or life sciences, requires long-term commitment. However, without these new products and services, other commercial space industries, such as transportation and infrastructure, will not be realized. A number of barriers, such as the upfront costs of accessing space, can be prohibitive for firms conducting research and development (R&D) that may or may not yield returns years in the future. NASA has developed two programs targeted toward overcoming these obstacles to market development:

(1) Joint Endeavor Agreements (JEA). For those companies that have committed resources and are in active product development stages, we offer the JEA. The JEA is a cooperative working arrangement which gives these firms access to NASA facilities and services and, in return, NASA receives the right to use the data which emanates from the commercial research efforts for its own use. We currently have 5 active JEA's with over 70 identified flight requirements. Of note is the recent success of a JEA experiment from the 3M Corporation flown on STS-26. The company is investigating the effects of low gravity on the behavior of certain organic materials.

New potential JEA partners have been identified for joint ventures this year. The following list is an indication of the breadth of the JEA Program and of the types of new markets and products emerging:

(a) Corabi International Telemetrics, Incorporated, has signed an agreement to explore a telemedical/telescience workstation for Space Station Freedom.

(b) A large oil firm is exploring the use of remote sensing systems to locate and survey nonrenewable resources.

(c) A small manufacturer of high temperature superconducting materials wants to explore commercial applications and possible space-based processing of its materials. To date, this company's materials have demonstrated superconducting characteristics superior to previously reported materials.

(d) A small technology firm is developing high efficiency photovoltaic systems, or solar cells, with a new concept that could potentially double the efficiency of presently used systems.

(e) A large utility firm is interested in commercially supplying auxiliary power in space for orbital systems.

(f) A small, value-added company has developed a concept of using hand-held photography in space to produce commercially viable photographic products.

It is important to remember that once a company, such as these and our other JEA partners, commit to long-term research efforts, they must proceed according to internal planning schedules. It is essential for NASA to have the ability to support in a timely manner these important development efforts.

(2) Centers for the Commercial Development of Space (CCDS). For those firms not in position to commit to long-term investment, NASA has established the CCDS Program. The CCDS's are consortia of university, industry, and government involved in early research and testing stages of potentially viable products or services. Through the CCDS's, NASA provides the financial backing needed for the applied technology phase, while academia and industry provide the imagination and the "bottom line" market approach necessary to bridge the gap between applied research and commercial application.

We believe this approach will ultimately result in large scale industry involvement in developing space-related technologies. These industry-driven technologies could, in turn, lead to a broad base of new markets and services. We are excited about the progress CCDS's are making. The 16 CCDS's currently involve the active participation of 48 universities and 128 companies. The success of CCDS's is demonstrated in the following achievements for this past year:

(a) The CCDS Management Operations Council was established to involve CCDS Directors in NASA planning. This coordinating body will help CCDS's share information, develop an overall program direction, and work collectively with NASA.

(b) An experiment on protein crystals grown in space was successfully flown on STS-26 by the Center for Macromolecular Crystallography at the University of Alabama-Birmingham. A second flight on STS-29, just completed recently, involved the conduct of further experiments with protein crystals whose structure can be analyzed and this will contribute to the eventual design of powerful new drugs to fight cancer, high blood pressure, organ transplant rejection, rheumatoid arthritis, and many other diseases.

(c) A commercially provided sounding rocket service has been selected by the Consortium for Materials Development in Space, a CCDS affiliated with the University of Alabama-Huntsville, to launch a payload of five experiments on materials processing in space this spring. This launch was successfully carried out by Space Services, Incorporated, on March 29, 1989.

(d) Up to 290 flight tests are being contemplated to carry out a flight technology program on 58 different materials or systems of interest now under development at 12 of our CCDS's.

As the seven CCDS's initiated in 1987 become more firmly established, the CCDS Program will become even more active. Through these research consortia, we can achieve two, sometimes conflicting, objectives. On the one hand, because private capital is at risk, CCDS's take a "market-driven" approach to innovation, emphasizing production requirements and market demands. On the other hand, CCDS's have the resources and the time to invest in the lengthy transition from public research to private development, because government seed money is provided. When the CCDS industrial partners decide that potential returns warrant long-term commitments of resources, they may then pursue a JEA arrangement. This working partnership can help ensure that U.S. commercial space research will successfully compete in the international environment.

e. Evolution of the OCP Flight Program. Formation of consortia such as CCDS's, and establishment of JEA partnerships will amount simply to intellectual exercises if the resulting projects do not have access to space in a timely manner. OCP is developing a flight plan to meet these anticipated needs. We have been allocated 31 percent of the secondary payload space on non-Department of Defense flights for commercial use. It is important to ensure that this space is used judiciously, and is of optimum benefit to industry.

The first step in the development of such a plan is to develop realistic requirements. Working with CCDS's, we have identified real, near-term flight requirements and are putting in place those policies, plans, systems, and organizations to systematically develop a realistic flight program schedule for the future.

Using these requirements as a base, we can extrapolate the requirements to meet anticipated new JEA's, and future potential commercial enterprises. The system OCP has initiated is working and is exemplified by the fact that a year ago there were only 10 specifically identified CCDS payload flight opportunities and, as of today, we have identified 150 of 290 eventually contemplated.

We are using our expertise to assist CCDS's and JEA partners in developing hardware that both meets NASA requirements and is designed in such a way as to gain quick access to the Shuttle should openings in the manifest occur late in the planning cycle. We have been successful in this also. For example, in CY 1989, we anticipated having opportunities to fly two commercial payloads, but now, because we have been able to assist our commercial partners in being able to take advantage of opportunities, may be able to fly up to seven payloads. Our near-term and strategic planning efforts are designed to ensure that developing space enterprises fly in a timely manner through a well defined and structured flight schedule that supports maturing industries regardless of their desired access to space mode.

This has in part been made possible through the development of new management tools. We have developed several management tools to make this new frontier more easily understood by the CCDS's and the private sector. These tools include the following: an STS Carrier Handbook of characteristics of STS compatible carriers; a Catalogue for Commercial Users which is a national inventory of resources available for commercial space users; videos and other documents that can be used as tutorials; and, documentation for preflight opportunities and the development of screening criteria and mechanisms that serve as guidelines for all commercial payloads.

f. Other Significant Activities. NASA is working to stimulate the market for value-added services derived from remote sensing technology. By developing the markets, requirements for new instruments and platforms will be driven by need. Research in commercial development of remote sensing technology is being led by two CCDS's at the Ohio State University and the Institute for Technology Development, near the recently established Earth Observations Support Office at NASA's John C. Stennis Space Center. Through improvements in sensor technology and data handling and interpretation techniques, the CCDS's hope to achieve a real-time satellite mapping capability. OCP is also jointly sponsoring 20 research projects in scientific and commercial remote sensing with the Office of Space Science and Applications.

In August 1988, NASA and SPACEHAB, Incorporated, signed a Space Systems Development Agreement for launch of SPACEHAB's commercially developed and manufactured module. SPACEHAB is a pressurized metal cylinder that fits in forward portion of the Shuttle payload bay and connects to the crew compartment through the orbiter airlock. It increases the pressurized working space on the orbiter by 1,000 cubic feet. Commercial ventures and sponsored research requiring man-tended access to the environment of space will be the primary target market for this venture. NASA has committed to six Shuttle flights for SPACEHAB modules beginning in 1991 and has manifested SPACEHAB on five flights: STS-51 (November 1991), STS-61 (September 1992), and STS-71 (January 1993), STS-79 (January 1994), and STS-86 (July 1994).

In addition to signing three new facilities use agreements with expendable launch vehicle (ELV) firms this year, NASA is trying to bolster the transportation industry by enhancing the development of the Nation's commercial sounding rocket capability. NASA is encouraging the CCDS at the University of Alabama-Huntsville to commercially solicit sounding rocket launch services for

CCDS experiments. This activity is not only supporting the launch industry, but also new product development. We are continuing to examine other mechanisms for delivering small payloads into low-Earth orbit.

In June 1988, we issued a Request for Expressions of Interest for private sector use of expended Shuttle external tanks. Ten organizations responded with proposals. OCP conducted a preliminary screening of these proposals and, as a result, three proposals remained for further technical, safety, and business evaluations. The Office of Space Flight is currently performing these detailed reviews. We also signed a Memorandum of Agreement in December 1988 with the University Corporation for Atmospheric Research, granting them use of space within five designated external tanks, on a suborbital basis.

And last, but certainly not least, we have initiated a number of studies to determine the impact of transportation costs on entry decisions by the private sector. If the cost of getting into space is prohibitive, companies will not make the decision even to start a research program. We need appropriate flexibility in our pricing policies so that we do not discourage entering companies from even beginning their research. It is also necessary to insure that government-offered services do not preclude or compete against commercial sector initiatives.

g. FY 1990 Commercial Use of Space Budget Request. NASA's direct efforts to encourage the commercial development of space is represented by a FY 1989 budget of $189 million and a FY 1990 request of $312 million excluding the ACTS. These monies, in addition to the OCP budget, include funding for research in microgravity sciences, research and hardware in the Office of Space Science and Applications, and purchases of commercial launch services in the Office of Space Flight.

The OCP budget request of $38.3 million for FY 1990 Commercial Use of Space is to fund those activities for which my office has the direct implementation responsibility. The FY 1990 OCP Commercial Use of Space request will be used to carry out the following:

(1) the basic CCDS grants and necessary augmentations;

(2) pilot projects, including CCDS commercially purchased sounding rocket services, commercially developed space processes, and centralized launch support operations for CCDS and JEA payloads;

(3) system engineering and integration support for CCDS and JEA payloads in OCP and the National Space Transportation System;

(4) optional service support for Space System Development Agreement customers; and,

(5) NASA Center projects including remote sensing application studies, the sharing of needed Center facilities and services for commercial partners, and supply of common carriers for selected payloads.

TECHNOLOGY UTILIZATION

Increasing emphasis is being placed on the transfer of government-funded technology to the private sector as a way of improving the Nation's competitive posture. Recent legislation and executive orders have directed federal agencies to increase their efforts in moving new technologies to industry. We have responded by conducting a thorough review of our Technology Utilization Program and incorporating the results into a new strategic plan. The plan will be used as a guideline for the effective transfer of NASA and NASA-sponsored technology.

NASA also was the first federal agency to formally distribute its patent royalty income as required by P.L. 99-502. On June 3, 1988, checks totaling $56,944 were mailed to 35 present and former NASA employee-inventors. The checks paid the inventors' share of NASA's patent royalty income received between the effective date of the Federal Technology Transfer Act of 1986 (October 20, 1986) and December 31, 1987. In addition, NASA is in the process of distributing $61,000 in royalties received during the past year.

a. Dissemination. A major element within the technology transfer program is the **Tech Briefs** publication. Through the publication, descriptions of NASA research innovations are currently distributed to approximately 200,000 domestic subscribers annually. The commercially produced magazine has published nearly 13,000 new technology reports since its beginning and has generated more than 1.5 million requests for more detailed information. The number of issues published annually is increasing from 10 to 12 per year because of increased interest.

NASA's annual **Spinoffs** publication continues to report NASA's many space technology spinoffs to the private sector. More than 600 items have been reported since its inception. The Spinoff Hall of Fame, sponsored and managed by the U.S. Space Foundation, was officially opened in Colorado Springs last year. Five NASA technologies were selected for induction. Further NASA technologies are scheduled for selection into the Hall of Fame during the spring of this year.

NASA is currently involved in a study to assess the economic impact of some of the spinoffs and applications reported in the **Spinoff** magazine. Tangible statistics on the impact of technology transfer are often difficult to measure or summarize. However, researchers have traced nearly 350 applications publicized in the annual reports and have obtained estimated revenues and cost savings that may be attributed in part or in whole to NASA programs. These NASA spinoffs have resulted in economic benefits from contributions to sales or savings in the billions since 1978. The study is still in progress, but the findings thus far strongly illustrate the importance of technology transfer. The second phase of this study, now underway, is attempting to define the total environment of the more than 20,000 applications which have been reported to exist, and it is our hope to quantify the economic benefits within a period of 12 months thereafter.

b. Industrial Applications Centers (IAC) and Affiliates. NASA supports a nationwide network of IAC's whose over 10,000 yearly industry clients have access to nearly 100 million scientific and technical documents in the NASA data bank and over 400 other computerized data bases. IAC affiliates are geographic extensions, similar to branch offices, of NASA IAC's and work primarily through state university-based industry technical assistance centers, small business assistance centers, and similar organizations. Currently 40 states have such affiliates linked to NASA's technology transfer infrastructure. Discussions are currently underway in seven additional states to establish linkages with the NASA network.

NASA has entered into a blanket agreement with the Federal Laboratory Consortium (FLC) that links the IAC network with approximately 500 FLC laboratories. Through this agreement, small and large business firms can use access points within their home states to determine availability of federal technology relative to their needs. NASA is continuing to work to further expand private sector access through other federal- and state-supported industry assistance activities, including the more than 500 Small Business Development Centers, Economic Development Agency Centers, and the proposed Department of Commerce Hollings Centers.

c. AdaNET Software Repository. To further strengthen and enhance technology transfer activities, NASA is continuing the planning and implementation of the AdaNET Program. The AdaNET Software Repository is intended to be a self-supporting commercial organization to provide users of Ada with information sharing and depository services. It will operate on a for-profit basis recovering cost through charges levied for services offered. Establishing an outlet for Ada software will benefit the private sector by giving added capability for solving many industrial and manufacturing problems. Access will be available electronically through network services provided under commercial agreements.

The AdaNET Program is currently in Phase II of its implementation plan which is to develop a revenue support structure for recovery of initial costs, a model license agreement for use with owners of Ada technology and for consumers, and organizational documents and governing policies. In Phase III of the project, subject to funding availability, the approved plan will be implemented. AdaNET is targeted to become self-sustaining through client income by 1991.

d. Technology Applications. Application projects were first established to provide direct NASA assistance in promoting secondary use of aerospace technology. Problems are identified by private firms or other organizations and potential solutions through NASA technology are studied. There are currently over 80 projects underway at 9 NASA field installations. In FY 1990, NASA will continue to broaden applications team responsibilities for brokering industrial client needs.

Examples of FY 1989 and FY 1990 technology projects include the following three examples:

(1) An instrument and technique for measuring the depth of skin burns. This project resulted from an observation that the burn damaged and healthy skin/tissue interface produces an ultrasonic reflection. Since the medical treatment differs substantially between second and third degree burns, and since the determination of the degree of a burn is now largely subjective and prone to error, the project was initiated to fill a need for a quantitative method for determining the depth of burns.

(2) A low-powered laser instrument which can precisely map the cornea of the human eye and provide accurate data for use by a surgeon during radial keratectomy procedure. The project involves the development of a rapid scanning system that would use visible light and would provide a raster scan pattern of the cornea. A small desktop computer would be used to synchronize the scanner and electronics to record data and plot the contour in real time with an accuracy of several microns in depth. The data would then be presented as a contour map.

(3) The Stirling engine, an external combustion engine which, when compared with conventional internal combustion engines, offers a number of unique advantages. It is a high torque engine that operates at a constant speed. It uses one spark plug, needs no muffler, emits no noxious gases, and can use any kind of fuel. In addition to use in vans and trucks, it is also under consideration for irrigation pumping and mobile processing in agriculture, drying processes in the lumber industry, and for use on trawlers, dredges, and shrimp boats in the fishing industry. Given its many advantages and its versatility, the Stirling engine may have significant impact on the U.S. transportation and processing industries.

A multiyear, multiphase demonstration program was created by an industry/government team to obtain early operation and performance data; evaluate integrity, reliability, and durability; and accelerate the development of the Stirling engine. In Phase I, a first generation Mod I Stirling engine was operated for 1,300 hours and nearly 7,000 miles using unleaded gasoline and JP-4 aircraft fuel in an Air Force van. This operational experience with the Stirling-powered van is providing the first "real world" data for transportation applications. No problems were identified.

e. FY 1990 Technology Utilization Budget Request. In FY 1990, the budget request for the Technology Utilization Program is $22.7 million, which money will be used to accomplish the following activities:

(1) broadening of application projects to assist NASA IAC's in bringing together industrial client problems with existing aerospace technologies, leading to project definition and industry-driven cooperative projects, thus enhancing the productivity and competitive posture of U.S. industry;

(2) improving the capability of the technology utilization offices at the NASA field installations to increase the level of technology transfer activities by means of a microcomputer-based system that efficiently stores data and facilitates timely access to new technologies developed in NASA's R&D programs. This network, the Technology Utilization Network System (TUNS), completes the linkage of the NASA technology utilization field installation

offices, the NASA Software Repository (COSMIC), the NASA Scientific Technical and Information Facility (STIF), and IAC's to provide a quicker distribution of new technologies that has previously been possible;

(3) increasing new technology identification, evaluation, reporting, and more efficiently packaging these new technologies for publications, thereby stimulating increased industrial interest and participation in NASA's Technology Utilization and Commercial Use of Space Programs;

(4) increasing the utilization and expanding the role of NASA's IAC's (industrial outreach agents) as a unique network to serve as NASA's surrogate in aligning U.S. industrial interests in space commercialization as well as opportunities for terrestrial commercialization of advanced technologies derived from NASA's R&D programs; and,

(5) promoting awareness of NASA's Technology Utilization Program and resources available to the public and private sectors through a broad array of program materials, seminar, and conferences. Industrial outreach will be expanded by efforts to identify additional nonaerospace users of NASA's technologies.

SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM

A growing number of small businesses are developing new commercial products as a result of research funded through NASA's SBIR Program. The Program, enacted through the "Small Business Innovation Development Act of 1982," strives to stimulate technological innovation in the private sector, strengthen the role of small business in meeting Federal R&D needs, increase the commercial application of federally supported research results, and foster and encourage participation by minority and disadvantaged persons in technological innovation.

Participating agencies establish SBIR programs by reserving a statutory percentage (presently 1.25 percent) of their extramural R&D budgets. This reserve is to be awarded to small business concerns for R&D during the first two phases of a uniform, three-phase process. The funding instruments used by NASA in both Phases I and II programs are contracts rather than grants or cooperative agreements. All contract awards are contingent on the availability of Federal Government funds. The Phase III activity, where appropriate, is conducted by small business using non-Federal funds to pursue commercial applications based on its government-funded SBIR activities through Phase II, or may entail continued research, development, and production procurement funded by the government using non-SBIR set-aside monies.

Since 1983, NASA has spent or committed more than $207 million for 983 Phase I and 360 Phase II contracts. These contracts have been placed with 503 small businesses in 40 states. The following table shows the increasing participation of small businesses in the SBIR Program. During FY 1988, we received 2,379 proposals for Phase I contracts. This represents a 30 percent increase over the number submitted in the prior year.

NASA
SMALL BUSINESS INNOVATION RESEARCH PROGRAM GROWTH

Program Solicitation Year	Phase I		Phase II	
	Proposals	Awards	Proposals	Awards
1983	977	102	92	58
1984	919	127	113	71
1985	1,164	150	129	84
1986	1,628	172	154	85
1987	1,826	204	179	100
1988	2,379	228	N/A	N/A
Totals To Date	**8,893**	**983**	**667**	**398**

Based on the FY 1990 budget request, the SBIR budget for FY 1990 is estimated to be $71.9 million, from which we anticipate considerable growth in the numbers of SBIR contracts and small businesses participating in NASA's R&D programs.

To assess the effectiveness of the initial SBIR Program, NASA conducted an evaluation last year of the first two groups of completed SBIR Phase II projects. Our study showed that 39 of the group of 73 projects completed during 1986 and 1987 were already being applied to current NASA program objectives or planned future activities, and that the quality of these SBIR projects was judged by NASA field installations to be as high or higher than most comparable research they fund through other R&D means.

Our study also found that at least 18 of these first 73 SBIR projects had already found commercial applications, or were currently being developed for commercial applications, through the private sector.

Both the NASA applications and the early commercial development results are remarkable considering the brief time periods that had elapsed since project completions. We will continue to track the first completed projects and all current SBIR projects as they progress, paying increased attention to the realization of their commercial potentials.

During 1988, the General Accounting Office (GAO) also conducted an independent study of the SBIR Program. Their report to the Congress confirmed that, for NASA, SBIR has become an effective technique for increasing the use of small business technological capabilities in government programs, and that it has been enthusiastically received by research managers at the NASA field installations. While the GAO report did not concentrate on commercial applications, their findings also identified a number of government SBIR project results which have met with commercial success.

In summary, NASA believes that SBIR is an important step in forging essential links with private industry, particularly with technically strong, entrepreneurial small businesses. We are convinced these links not only benefit the NASA mission in a material way, but also are essential to strengthening U.S. international competitiveness.

PRIVATE SECTOR INVOLVEMENT IN INFRASTRUCTURE FACILITIES AND SYSTEMS

American industry has, for many years, been an important partner with government in implementing U.S. civil space programs that, taken together, have produced an unsurpassed record of achievement and excellence. Indeed, the President's commercial proposals build on our strong and experienced aerospace industry base while reaching out to draw in the resources and skills of commercial sectors that heretofore have not been part of the traditional space enterprise.

The overarching objective of these commercial initiatives is embodied in U.S. National Space Policy which states that, "expanding private sector investment in space by the market-driven commercial sector generates economic benefits for the Nation and supports governmental space sectors with an increasing range of space goals and services." Recently, President Bush confirmed his support for this objective and stated that as a fundamental principle of his Administration's space policy, "private sector initiatives in space should be strongly encouraged, including creation of additional research and manufacturing opportunities." NASA fully subscribes to the goal of expanding U.S. private sector participation in our Nation's space program. Properly done, private sector investment in space projects can reduce government costs with no loss in quality or performance. Of equal or even greater importance, the development of a healthy commercial space sector can contribute significantly to advancing overall U.S. technological leadership and improving our Nation's economic international competitiveness. Other countries--both East and West--are actively investing in and marketing space goods and services on a global basis. After more than 30 years of undisputed leadership, we cannot afford to be anywhere but on the leading edge of the emerging space economy of the 21st century.

United States industry has been an important part of the space program from the beginning. However, the concept of the private sector investing--that is, putting capital at risk--in space-related activities is with a few notable exception, a relatively new idea. For many years, space operations, both in orbit and on Earth, were considered the responsibility of government, with the lone but significant exception of communications satellites. While the situation is changing, the U.S. private sector has been slow to enter the space field on a commercial (as opposed to contractor) basis. There are many reasons for this, including the large costs that are often involved, the fear of government competition, the risks associated with long and uncertain payback cycles, and the lack of identified and reliable markets.

NASA is actively engaged in promoting and supporting commercial space activity on a broad front. However, NASA does not claim to have all of the answers to what is a complex and long-term challenge. In many cases, we at NASA are in an exploratory mode. This is especially true in the area of space-related infrastructure where NASA is currently seeking to determine from the best source possible--the private sector itself--when and under what circumstances its members are prepared to invest their resources.

The President's FY 1990 budget proposed several specific infrastructure projects as candidates for private investment. They are:

- the Advanced Solid Rocket Motor (ASRM) Facility,
- the Space Station Processing Facility (SSPF),
- the Neutral Buoyancy Laboratory (NBL),
- the Observational Instruments Laboratory (OIL),
- the Space Station Docking Module, and
- the Extended Duration Orbiter (EDO) Kit
- the Flight Telerobotic Servicer (FTS)

NASA's commitment is to pursue the potential for private investment in each of these projects. "Pursue the potential" must be emphasized because some have concluded that NASA has already determined that the private sector can and will invest in each project and that we are asking the Congress to endorse or approve such a determination. That is most assuredly not the case. It bears repeating that the U.S. is still in the early stages of building a commercial space industry. Outside of communications satellites, the developing ELV industry, and perhaps the remote sensing field, NASA does not have a lot of direct experience--either good or bad--to draw upon. We have a broad set of guidelines embodied in the National Space Policy, but those guidelines, while necessary and helpful, must be implemented by laying out some specific infrastructure opportunities and seeing whether and how the private sector responds. That is what NASA is doing with these projects.

By design, the projects are diverse, including both terrestrial facilities and flight systems in various stages of conceptualization or acquisition. These commercial initiatives were initially selected for exploration based on: (1) previous expressions of interest from industry sources, or (2) their potential for multipurpose; (i.e., government and industry use), or (3) their conformance with the National Space Policy which directs that agencies will seek to rely to the greatest extent feasible on the private sector for goods and services. Because of their diversity, the form and scope of prospective private sector investment will likely differ from one to the other. While NASA certainly intends to make a good faith, energetic effort in each case, we may not succeed in attracting acceptable commercial proposals in every instance. Yet, at this stage, we stand to learn a great deal from our setbacks as well as from our successes. However, we cannot succeed and we cannot learn unless we are allowed to try.

Against this backdrop, I would like to describe four specific steps NASA is taking to meet commercial objectives with respect to these infrastructure projects:

a. First, NASA is, wherever practical, already inviting private sector firms to express interest in and make specific proposals for investing private funds in these projects. For example, in the cases of the SSPF at Kennedy Space Center and the NBL at Johnson Space Center, we placed notices late last year in the **Commerce Business Daily** soliciting responses from private sector firms interested in investing in these facilities. Fourteen substantive responses were received on the SSPF and six responses were received on the NBL. The nature of these responses suggested to us that there were sufficient grounds for proceeding further down the commercial path on these facilities. Accordingly, we formed procurement development teams at the two field installations who developed acquisition strategies which have led to draft Requests for Proposals (RFP) providing specifically for private investment. NASA has issued one of these draft RFP's for comment. The second is pending release. Prior to release of the final RFP's, NASA will consult closely with the Subcommittee.

In contrast to the other facilities, the ASRM formal contractor selection process was completed when Lockheed Missile Systems Division was selected on April 21, 1989, to enter into formal negotiations. NASA will negotiate with Lockheed on the basis of privately financed construction.

The EDO project is even further down the track, since the prime contractor for that work has already been selected through modification of an existing contract. In this case, we have approached the prime contractor, Rockwell International, and solicited its interest in a private investment approach probably in conjunction with another private firm, Teledyne Brown, which has already indicated a possible investment interest in the EDO system. Rockwell has indicated a desire to explore private investment options with NASA and discussions have recently begun.

b. Second, NASA is seeking to ensure that private firms which are interested in pursuing investment approaches can come forward with confidence that the risks they assume will be reasonable and not arbitrary. In particular, it is NASA's view that private parties will propose and provide financing for major projects, like the ground-based facilities proposed in the President's budget, only if they can be sure in advance that their investments are protected through government assumption of liability in the event these projects are terminated by the government for its convenience, and they are thus denied the opportunity to make normal commercial profits. To this end, NASA has forwarded to Congress two pieces of proposed legislative language. The first would provide NASA with liability authority to support award of the ASRM contract now being negotiated. As Dr. Fletcher indicated last fall and Mr. Myers reiterated two weeks ago, receiving this authority promptly is vitally important and will allow us to move the ASRM program expeditiously forward. The second legislative initiative is contained in the Administration's proposed FY 1990 NASA Authorization Bill and would apply to the other ground facilities. It would amend the Space Act to grant NASA legal authority to assume liability in excess of available appropriations for privately financed special purpose facilities.

c. Third, NASA is, as a matter of policy and practice, looking for private sector proposals that represent investments not loans. In short, we are not seeking, via these projects, simply to borrow money from industry, unless there are specific and demonstrable reasons for doing so. While it is generally unlikely that the private sector could offer financing at terms better than those obtained by the Government, there are cases, such as the ASRM facility, where private financing makes sense. This approach is expressly permitted by Administration policy which allows lease-purchase arrangements for special-purpose facilities on a case-by-case basis. Accordingly, NASA intends to examine closely and to analyze independently each proposal it receives from industry. We will look most favorably at those proposals which, irrespective of their potential for marketplace stimulation, are economically advantageous to the government. In most cases, this means proposals where the private sector is willing to put its own capital at risk. For example, in preparing the RFP's for the SSPF and the NBL, NASA intends to explicitly specify that proposers should address the potential for lowering costs to the government by providing over time for multiple use or shared use of these facilities. When proposals are received in response to these and similar RFP's, we will conduct economic benefit analyses as part of the evaluation processes. At this point, it is possible that the OIL is a special-purpose facility not readily amenable to shared use, and if we decide to seek private financing there, we may need to analyze what other factors should be considered.

We do not underestimate the difficulty of measuring in advance a project's potential for fostering viable space markets or actually reducing government outlays in the long term. It is clear that no single approach to the commercial development of space will work in every instance, especially in nonfacility cases. With the EDO, for example, it may be appropriate to consider an approach whereby the private invester recoups its initial investment from the government through a more or less traditional take or pay approach, but depends on user fees from commercial and foreign users for any return on that investment. In other cases, the government may seek to reduce its hardware costs and foster space commerce by negotiating more favorable contract terms in return for granting the winning contractor exclusive commercial rights to any technology that results from the project. We will need some flexibility to consider innovative approaches proposed by the private sector.

There are also other distinctions implied by the concept of private sector investment instead of private sector financing. NASA envisions the private sector becoming an equity partner, bringing to the table new ideas and management expertise to a much greater degree than currently is the case under normal government contracting. This addition of intellectual, as well as financial, capital is absolutely essential if NASA is to achieve the goal of creating national space assets that safely and effectively serve multiple purposes at reduced costs.

d. Fourth, NASA has made it clear that private investment must not come at the expense of important program requirements and schedules. In this respect, the facilities named earlier are all key in-line operational and development facilities. NASA has focused most of our early energies on them precisely because of their critical nature. If acceptable and timely proposals for private investment are not forthcoming, alternative funding approaches will be required.

With regard to the nonfacility projects: contacts with Rockwell International about a private investment approach to EDO have been initiated and we are currently in a position to analyze and, if appropriate, act on any near-term proposal without serious schedule risk. Quite frankly, the Space Station Docking Module is not a time-critical item at this stage and, as a result, we have chosen to focus our principal attention on the other projects. The Space Station Telerobotic Servicer (FTS) was also considered for private sector investment. However, NASA has now modified this approach after a further assessment of the project. NASA is reserving the option through the negotiations of the FTS contract to offer to the U.S. private sector intellectual property rights and rights to access and use FTS production equipment, tooling and facilities with appropriate technical support to help the private sector develop future applications. NASA is proceeding with FTS development and contractor selection on the planned schedule. NASA is, however, committed to exploring opportunities for expanded private sector investment and involvement in meeting all future Space Station requirements and will examine the potential commercial benefits offered by the docking module in the near future. However, NASA will also need to carefully study the safety and operational aspects of any proposal that includes critical manned flight systems like the docking module. NASA will assure that the safety and protection of human life as related to the Nation's space program will not be compromised by our commercialization endeavors.

We are aware of the Committee's interest in the Commercially Developed Space Facility (CDSF). As you know, Mr. Chairman, the NASA Authorization Act for FY 1989 required NASA to contract for two independent studies: one with the National Research Council (NRC) assessing the potential role and value of a CDSF, and the other with the National Academy of Public Administration (NAPA) assessing economic aspects, including the expected program cost. These two studies have been completed and the study reports have been made available to the Committees of both houses. The NRC study concluded that in the period prior to Space Station operations, no CDSF is required based on the current state of microgravity research and the projected need for manufacturing capability. The NAPA study concluded that the estimated cost of developing a CDSF would be over two billion dollars. However, the RFP was never released and there is very little specific information on which to determine the actual price at which the private sector could have provided CDSF services. NASA, as required by the Act, has forwarded a report to Congress based on these studies and does not plan to take any additional action on the CDSF proposal. The report was coordinated by the National Space Council staff.

In summary, NASA is fully committed to encouraging and supporting expanded private sector investment in space. Private sector investment cannot substitute for government leadership and program direction. American interests are best served when government and industry are combining their respective strengths and working cooperatively together. Indeed, our foreign commercial competitors, frequently working in close collaboration with their governments, are making significant investments in space-related research and supporting hardware. If the U.S. is to remain the world's leader in space, we must utilize fully the resources of both the public and private sectors.

This concludes my prepared remarks, Mr. Chairman. I would be pleased to respond to questions.

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

SPECTRUM OF PRIVATIZATION/ COMMERCIALIZATION ACTIVITIES

TYPE	TYPICAL EXAMPLES	STATUS
INFORMATION SYSTEMS	• COMMUNICATIONS SATELLITES • REMOTE SENSING	• MATURE INDUSTRY BUT NO RESEARCH AND DEVELOPMENT OR LONG-RANGE STRATEGY • LANDSAT SYSTEM IN TROUBLE NEED TO DEVELOP PRIVATE MARKETS
TRANSPORTATION	• EXPENDABLE LAUNCH VEHICLES (ELV) • SOUNDING ROCKETS	• PRIVATIZATION AGREEMENTS IN PLACE WITH GOVERNMENT • 15 COMPANIES OFFERING SERVICES. ALL DEPEND ON GOVERNMENT AS A CUSTOMER
INFRASTRUCTURE	• PRIVATELY PROVIDED CARRIERS -- SPACEHAB • PRIVATELY DEVELOPED PROCESSING EQUIPMENT • PRIVATELY DEVELOPED UPPER STAGES	• 13 COMPANIES OFFERING SERVICES • ALL CURRENTLY DEPEND ON GOVERNMENTS AS A CUSTOMER
NEW PRODUCTS AND SERVICES	• PHARMACEUTICALS • CRYSTALS • SERVICES	• EMBRYONIC 5 + YEARS DEVELOPMENT ANTICIPATED • JOINT ENDEAVOR AGREEMENT AND CENTER FOR THE COMMERCIAL DEVELOPMENT OF SPACE PROGRAMS IN PLACE AS INCENTIVES FOR INDUSTRY INVOLVEMENT
FULL COMMERCIALIZATION	• PRIVATE MARKETS IN ALL TECHNOLOGICAL FIELDS SUPPORTED BY PRIVATELY DEVELOPED INFRASTRUCTURE AND TRANSPORTATION	• INDUSTRY INVOLVEMENT NEEDED • STRATEGIC PLAN NEEDED • IMPLEMENTATION PLAN NEEDED

CP- 4041M
04.26.89 ..TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE (CCDS)

TECHNICAL DISCIPLINE	# INVOLVED	CCDS'S
1. AUTOMATION AND ROBOTICS	2	• UNIV. OF WISCONSIN, MADISON, WI • ENVIRON. RESEARCH INST. OF MICHIGAN, ANN ARBOR, MI
2. LIFE SCIENCES	3	• UNIV. OF COLORADO, BOULDER, CO • PENN STATE UNIV., UNIVERSITY PARK, PA • UNIV. OF ALABAMA, BIRMINGHAM, AL
3. MATERIALS PROCESSING IN SPACE (MPS)	5	• BATTELLE, COLUMBUS, OH • UNIV. OF ALABAMA, HUNTSVILLE, AL • VANDERBILT UNIV., NASHVILLE, TN • CLARKSON UNIV., POTSDAM, NY • UNIV. OF HOUSTON, HOUSTON, TX
4. REMOTE SENSING	2	• INST. FOR TECH. DEVELOP., STENNIS SPACE CENTER, MS • OHIO STATE, COLUMBUS, OH
5. SPACE POWER	2	• AUBURN UNIV., AUBURN, AL • TEXAS A&M UNIV., COLLEGE STATION, TX
6. SPACE PROPULSION	1	• UNIV. OF TENNESSEE SPACE INSTITUTE, TULLAHOMA, TN
7. SPACE STRUCTURES AND MATERIALS	1	• CASE WESTERN RESERVE UNIV., CLEVELAND, OH

SUMMARY: THERE ARE CURRENTLY SEVEN TECHNOLOGY DISCIPLINES REPRESENTED IN THE CCDS PROGRAM. THE MAJORITY OF THE CCDS'S ARE CONDUCTING RESEARCH IN MPS.

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE
UNIVERSITY AFFILIATES

48 UNIVERSITIES

AKRON UNIVERSITY
CASE WESTERN RESERVE UNIVERSITY
CLARKSON UNIVERSITY
CLEVELAND UNIVERSITY
OHIO STATE UNIVERSITY
WASHINGTON STATE UNIVERSITY
WORCESTER POLYTECHNIC
PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY OF MAINE
MURRAY STATE UNIVERSITY
FLORIDA STATE UNIVERSITY
MONTANA STATE UNIVERSITY
UNIVERSITY OF SOUTHERN MISSISSIPPI
PURDUE UNIVERSITY
UNIVERSITY OF ARKANSAS
UNIVERSITY OF ALABAMA - HUNTSVILLE
UNIVERSITY OF ALABAMA - TUSCALOOSA
UNIVERSITY OF FLORIDA - GAINESVILLE
MISSISSIPPI STATE UNIVERSITY
UNIVERSITY OF ARIZONA
GEORGIA INSTITUTE OF TECHNOLOGY
UNIVERSITY OF CALIFORNIA - RIVERSIDE
UNIVERSITY OF CHICAGO
UNIVERSITY OF WASHINGTON - SEATTLE
UNIVERSITY OF TEXAS - GALVESTON
UNIVERSITY OF MISSISSIPPI
UNIVERSITY OF MICHIGAN
MICHIGAN STATE UNIVERSITY
UNIVERSITY OF CALIFORNIA - BERKELEY
ALABAMA A&M UNIVERSITY
RENSSELAER POLYTECHNIC INSTITUTE
UNIVERSITY OF ILLINOIS - URBANA
UNIVERSITY OF WISCONSIN - MADISON
KANSAS STATE UNIVERSITY
UNIVERSITY OF UTAH
UNIVERSITY OF COLORADO - DENVER
FLORIDA A&M UNIVERSITY
UNIVERSITY OF BUFFALO
UNIVERSITY OF SOUTH CAROLINA
UNIVERSITY OF TENNESSEE SPACE INSTITUTE
AUBURN UNIVERSITY
PRAIRIE VIEW A&M UNIVERSITY
LAMAR UNIVERSITY
UNIVERSITY OF TEXAS AT ARLINGTON
COLUMBIA UNIVERSITY
ARIZONA STATE UNIVERSITY
JEFFERSON MEDICAL COLLEGE
COLORADO STATE UNIVERSITY

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

PRELIMINARY LISTING OF CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE CORPORATE AFFILIATES

128 CORPORATE

3M
ABBOT LABORATORIES
ALCOA
ALLIED SIGNAL
ALZA
AMOCO CHEMICALS CORPORATION
APPLE COMPUTERS
ARMCO, INC.
ARTHUR D. LITTLE
ASTRONAUTICS CORP. OF AMERICA
AT&T
BALL AEROSPACE
BARNES ENGINEERING
BEAVER DAM EMERGING GROWTH
BEND RESEARCH
BIOCRYST
BOEING AEROSPACE COMPANY
CABOT CORP.
CENTRAL BIOMEDIA
CHROMATEM
COLUMBINE VENTURE FUND
COULTER
CREARE, INC.
CSAT
DANTEC ELECTRONICS
DEERE AND COMPANY
DELCO
DEVELOPMENTAL PLANNING & RESEARCH
DIGENE
DOW CHEMICALS
DUVAL COMPOSITES, INC.
E-SYSTEMS, INC.
E.I. DuPONT
EAGLE-PICHER, INC.
EASTMAN KODAK
EDISON POLYMER INNOVATION
EG&G
ELECTRIC POWER RESEARCH INSTITUTE
ELECTRO-OPTEK
ELECTROPORE, INC.
ELI LILY
ENDOTRONICS
ENGLEHARD CORP.

ENTECH, INC.
ESRI
FAIRCHILD
FORD AEROSPACE
FOSTER MILLER
FRED FERNSLER
FREEPORT MCMORAN
FRONTIER RESEARCH
GAMMEX, INC.
GELMAN SCIENCES
GENENTECH, INC.
GENERAL DYNAMICS
GENERAL ELECTRIC
GENERAL MOTORS
GEOSPECTRA, INC.
GOODYEAR
GRUMMAN CORP.
GTE
GULF STATE UTILITIES
HANFORD ENGINEERING LABORATORIES
HERCULES
HUTSON FERTILIZER
IATROMED
IBM ALMADEN
II-VI, INC.
INDUSTRIAL TECHNICAL INSTITUTE
INSTRUMENTS S.A., INC.
INTERGRAPH
INTERNATIONAL PAPER
ITA
JOHNSON CONTROLS, INC.
KMS FUSION
LEMONT SCIENTIFIC COMPANY
LOCKHEED
LUNAR RADIATION
MADISON KIPP, INC.
MARTIN MARIETTA AEROSPACE
MASSCOMP
MASTER BUILDERS, INC.
MAXWELL LABORATORIES
McDONNELL DOUGLAS CORP.
MERCK, SHARPE & DOME
METROLASER

MICKLEY & ASSOCIATESPEPCO
MONOCLONAL PRODUCTION
OCEANROUTES
OPTRA
PALEN FARMS, INC.
PEPCO
PERKIN-ELMER
PHILLIPS PETROLEUM
PHYTO FARMS OF AMERICA
PIERRE FABRE MEDICAMENT
PIERSON PRODUCTS, INC.
PPG INDUSTRIES, INC.
PRECISION SCIENTIFIC
PROCTOR & GAMBLE
QUANTUM TECHNOLOGIES
ROCKETDYNE
ROCKWELL INTERNATIONAL
SATURN CORP.
SCHERING CORP.
SCIENTIFIC ENTERPRISES
SEVRAIN TECH, INC.
SILICON SENSORS
SMITH, KLINE & BECKMAN
SNAP-ON-TOOLS
SOLAR ENERGY RESEARCH INSTITUTE
STRATEGY DEVELOPMENT
SUNDSTRAND CORP.
SUPELCO
SYMBOLICS, INC.
TECHNION, INC.
TECTRONIX
TELEDYNE BROWN ENGINEERING
TELEDYNE WAH CHANG
TRANS-TEMP
TRW
UPJOHN
VERSATEC
WATER TECH CORP.
WESTINGHOUSE
WYLE LABORATORIES
ZETACHRON
ZYNAXIS CELL SCIENCE

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

PLANNED PAYLOADS AND NUMBERS OF AFFILIATES FOR CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE AND JOINT ENDEAVORS

ORGANIZATION	PAYLOAD FLIGHTS BY CALENDAR YEARS								CURRENT TOTAL FLIGHTS	CURRENT NUMBER OF AFFILIATES	
	1988	1989	1990	1991	1992	1993	1994	1995-1999		INDIUSTRY	OTHER
3M	1	1	2	3	6	7	8	35	63	2	
INSTRUMENTATION TECHNOLOGY ASSOC.					1	1			2	5	
INTERNATIONAL SPACE CORP.					2	2	2	2	8	1	
BOEING					1	1	1		3	2	
ROCKWELL INTERNATIONAL		2							2	2	
BATTELLE		4	11	2	3	2	1		23	7	7
UNIVERSITY OF ALABAMA - BIRMINGHAM	1	3	4	4	3	2			17	12	9
UNIVERSITY OF ALABAMA - HUNTSVILLE		2	1	4	3	4	1		15	7	
VANDERBILT UNIVERSITY				1	4	4			9	9	3
CLARKSON UNIVERSITY					7	2			9	12	7
UNIVERSITY OF HOUSTON					1	2	1	3	7	6	2
UNIVERSITY OF WISCONSIN					3	2	2	1	8	13	1
AUBURN UNIVERSITY			2	4	4	2			12	4	8
CASE WESTERN RESERVE UNIVERSITY			1	2	1	1	2	3	10	7	
UNIVERSITY OF COLORADO		1	6	4	8	4	3		26	18	5
ERIM				4	5	6	2	1	18	7	3
PENNSYLVANIA STATE UNIVERSITY		1	4	5	2	1			13	11	
TEXAS A&M UNIVERSITY				1	1		1		3	14	11
UNIVERSITY OF TENNESSEE				1					1	5	2
TOTAL	2	14	31	35	55	43	24	45	249	144	58

CC - 2413 05/16/89 --TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

OFFICE OF COMMERCIAL PROGRAMS FLIGHT TESTS - 1989

FLIGHT	DATE	PAYLOAD	SPONSOR	AFFILIATES
STS-26	SEP 29, 1988	PROTEIN CRYSTAL GROWTH (PCG-II-1)	UAB CCDS	• BURROUGHS WELLCOME COMPANY • DUPONT CORPORATION • MERCK INSTITUTE FOR THERAPEUTIC RESEARCH • SCHERING-PLOUGH • UPJOHN
		PHYSICAL VAPOR TRANSPORT OF ORGANIC SOLIDS (PVTOS)	3M	N/A
STS-29	MAR 1989	PROTEIN CRYSTAL GROWTH (PCG-III-1)	UAB CCDS	• EASTMAN KODAK • ELI LILLY COMPANY • DUPONT CORPORATION • MERCK INSTITUTE FOR THERAPEUTIC RESEARCH • BIOCRYST LIMITED • UPJOHN • SMITH, KLINE, AND FRENCH • SCHERING-PLOUGH
STS-30	APR 28, 1989	FLUID EXPERIMENT APPARATUS (FEA-1)	ROCKWELL INTL.	N/A
STS-34	OCT 1989	POLYMER MORPHOLOGY (PM-1)	3M	N/A
STS-32	NOV 1989	FLUID EXPERIMENT APPARATUS (FEA-2)	ROCKWELL INTL.	N/A
		INVESTIGATIONS INTO POLYMER MEMBRANES PROCESSING (IPMP)	BATTELLE CCDS	• AMOCO

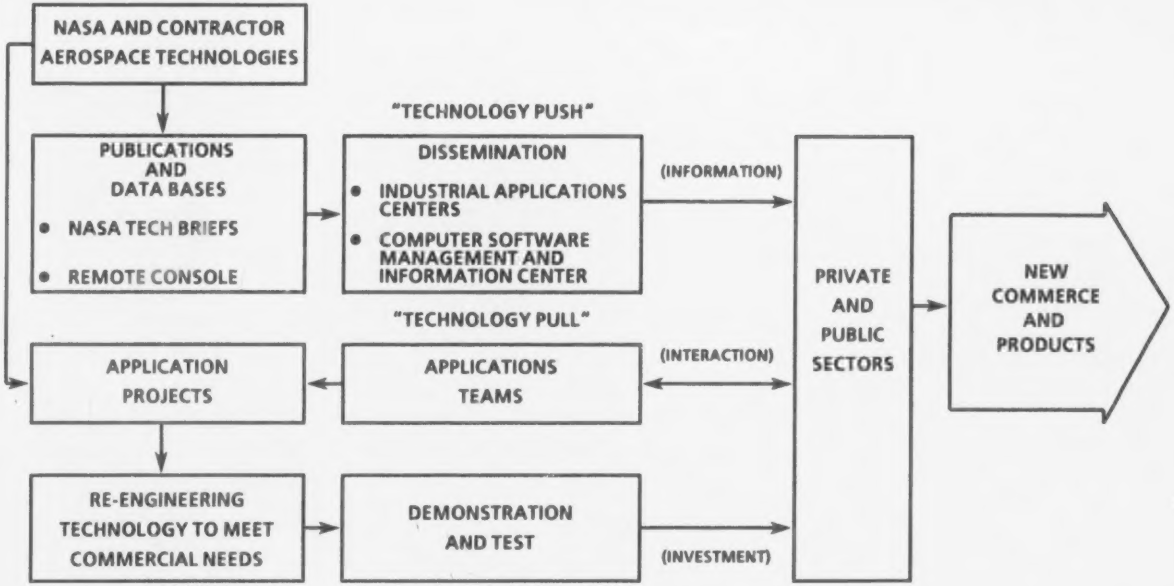
NASA
OFFICE OF
COMMERCIAL
PROGRAMS

OFFICE OF COMMERCIAL PROGRAMS FLIGHT TESTS - 1989 (CONTINUED)

FLIGHT	DATE	PAYLOAD	SPONSOR	AFFILIATES
STARFIRE-1 (COMM. SOUNDING ROCKET)	MAR 1989	• DEMIXING OF IMMISCIBLE POLYMERS • ELECTRODEPOSITION • POWDERED METAL SINTERING • FOAM FORMATION • ELASTOMER-MODIFIED EPOXY RESINS	UAH CCDS	• UNIVERSITY OF CALIFORNIA - BERKELEY • MDAC • TELEDYNE BROWN & TELEDYNE WAH CHANG • HERCULES, INC. • PHILLIPS PETROLEUM
		• MATERIALS DISPERSION APPARATUS		• ITA • TELEDYNE BROWN • RANTEK • BIOSERVE CCDS • PENN STATE CCDS • SUNY • UNIVERSITY OF WISCONSIN • NIST • UNIVERSITY OF ARIZONA
STARFIRE-2 (COMM. SOUNDING ROCKET)	OCT 1989	• DEMIXING OF IMMISCIBLE POLYMERS • ELASTOMER MODIFIED EPOXY RESIN • FOAM FORMATION • ELECTRODEPOSITION • POLYMER INVESTIGATIONS • BIOMODULE • POLYMER THIN FILM APPARATUS • BIOSERVE MINILAB	UAH CCDS	• UNIVERSITY OF CALIFORNIA - BERKELEY • PHILLIPS PETROLEUM • HERCULES, INC. • MDAC • BATTELLE CCDS • PENN STATE CCDS • MORTON THIOKOL • BIOSERVE CCDS
		• MATERIALS DISPERSION		• ITA • UNIVERSITY OF PENNSYLVANIA • TELEDYNE BROWN • RANTEK • BIOSERVE CCDS • PENN STATE CCDS • SUNY • UNIVERSITY OF WISCONSIN • NIST • UNIVERSITY OF ARIZONA • UNIVERSITY OF KENTUCKY

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

TECHNOLOGY TRANSFER PROCESS



NASA AND CONTRACTOR AEROSPACE TECHNOLOGIES

PUBLICATIONS AND DATA BASES
- NASA TECH BRIEFS
- REMOTE CONSOLE

"TECHNOLOGY PUSH"

DISSEMINATION
- INDUSTRIAL APPLICATIONS CENTERS
- COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER

(INFORMATION)

"TECHNOLOGY PULL"

APPLICATION PROJECTS

APPLICATIONS TEAMS

(INTERACTION)

RE-ENGINEERING TECHNOLOGY TO MEET COMMERCIAL NEEDS

DEMONSTRATION AND TEST

(INVESTMENT)

PRIVATE AND PUBLIC SECTORS

NEW COMMERCE AND PRODUCTS

CP-4143
11-29-88 --TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

NASA SBIR PROGRAM AWARD STATISTICS

PROGRAM SOLICITATION YEAR	PHASE I			PHASE II			PHASE I & II
	PROPOSALS	AWARDS	TOTAL FUNDING $M	PROPOSALS	AWARDS	TOTAL FUNDING $M	TOTAL PROGRAM FUNDING $M
1983	977	102	5.0	92	58	24.0	29.0
1984	919	127	6.3	113	71	32.5	38.8
1985	1164	150	7.4	129	84	39.3	46.7
1986	1628	172	8.5	154	85	39.2	47.7
1987	1826	204	10.0	179	100	47.9	57.9
1988	2379	228	11.3	NA	NA	NA	NA
TOTALS TO DATE	8893	983	48.5	667	398	182.9	220.1 (1) 231.4 (2)

NOTE: (1) TOTAL PROGRAM FUNDING SHOWN IS FOR FIRST FIVE PROGRAM SOLICITATION YEARS

(2) TOTAL PROGRAM FUNDING SHOWN IS FOR FIRST FIVE PROGRAM SOLICITATION YEARS, PLUS 1988 PHASE I

CR - 5006
02-23-89 --TEM

Senator GORE. Well, very good.

Before going to questions let me recognize Senator Robb and Senator Lott. If either of you have any opening statements.

OPENING STATEMENT BY SENATOR LOTT

Senator LOTT. Well, I would just, very briefly, Mr. Chairman, like to express appreciation for the hearing that you are having here today, and I want to congratulate Mr. Rose for the effort he is making in this commercialization of opportunities of what we are finding in space.

I have had the opportunity to talk with him personally and privately. I look forward to working with you in the future. I think this is a greatly underutilized area. I think it is absolutely essential that we find ways to properly expand commercialization of what we learned in space, and make sure that people understand, or know what is being done in that area.

I feel like, frankly, we have not done enough in this area in the past, and so I am pleased that we are having this hearing, and that you are putting the emphasis on it that you are. And I will look forward to asking you some questions as we proceed this morning.

Senator GORE. Very good.

Mr. Rose, in late May, as you indicated, the first report of the Commercial Program Advisory Committee is due to be released. That should be coming pretty quick.

Mr. ROSE. Yes, sir.

Senator GORE. Could you share with us today the general conclusions of this report, and highlight some of the 50 recommendations that I understand are contained in it. And tell us whether or not any of these CPAC recommendations will require legislation.

Mr. ROSE. Let me give you a quick make up of the report. We had the 18 CEO's and college kids broke themselves into subcommittees which included what one called Finance Subsidy Private Industry Incentives and Prospects.

The second subcommittee was International Competition and Cooperation.

The third was Commercial Space Policy, Stability and Constituency.

And the fourth was Public and Political Opinion Process.

And they have formed about 50 major recommendations to the subcommittee areas. Where they will also come back this summer and we will meet to discuss more specific recommendations that can be made in the four distinct areas of the market.

But I think it would be—we have taken some of the 50 and made them into what we call key recommendations that include four recommendations in the leadership and goal setting. A recommendation in—one recommendation in support to space enterprise; one in capital—that is the money. One in U.S. government as a customer; one in procurement; one in R&D tax credit.

And they perform, what we call key recommendations. I would hate to share them totally with you today, because they have not been reviewed. They are being reviewed today with the other—with the NASA Advisory Committee itself, and will then go to Admiral Truly for his understanding. And I think I would be out of place if I give you the recommendations before they have been adequately reviewed within the agency.

Senator **Gore**. We understand that. We are naturally curious and appreciate that summary.

Are they going to be NASA specific?

Mr. **Rose**. Some will be NASA specific, some will be—as I said before, I think they are going to have some recommendations that says what the leadership and goal setting should be as a nation.

Senator **Gore**. Government wide?

Mr. **Rose**. Yes.

Senator **Gore**. All right.

When will specific implementation plans be formulated for these recommendations?

Mr. **Rose**. Well, we have—being close to the committee, and have, working with it, we are already in the process of formalizing it. And in discussions with Admiral Truly yesterday, on his first day on the job, I am moving to have to him within 60 days, an implementation plan.

Senator **Gore**. All right. Very good.

I was recently told that there have been 45 major changes in U.S. commercial space policy over the past 30 years, and they have affected all sectors of space industry—everything from satellite communications to space transportation.

I also was told that more than half of those changes occurred in the last 8 years.

What can be done to provide a more stable and a more consistent policy toward space commercialization? And how does the instability that we have had over the last 8 years or so compare with other high tech industries in the United States?

Mr. **Rose**. Well, I believe that the instability with government policy as far as space commercialization goes, has been totally disruptive, because the government plays such an integral part in that.

Space still is not just a place as some people refer to it—it is still very hard to get there, and it takes a lot of technical knowhow; it is expensive yet. But if we do not explore it, and if we do not start developing it, and this is why I am saying from a competitive standpoint of view, we have got to do with.

So the goverment is an integral party to it. So whatever the government does can greatly influence industry.

In other high tech areas a lot of times the government simply, you know, does—is nowhere near—has the involvement than it does in the space area.

So, yes, it is quite disruptive. Being on the McDonnell-Douglas side for some 8–10 years in the first wave of looking at space as a place to make products, we consistently were pushed on the government to be consistent—to come up and agree that they will do certain supports.

What I am hoping will come out of our CPAC—the Advisory Committee was just what we called it—the Commercial Programs Advisory Committee—will help the National Space Council and interested parties in Congress to formalize—this is what we plan to do.

If we can come up and agree with a strategy, in general, across the government, I think the policies will become stable. But I do think that it is going to be—we all have to work at defining what it is we want to do as a nation. What are the proper roles of government and industry in each one of these areas of commercial space? That includes communications, transportation, infrastructure, new products and services.

So, we have got a lot of people working the issue now. If we can bring them together effectively, then I think we can get some stability.

Senator Gore. Let me just ask a couple of more on this round, and then recognize my colleagues.

I am told that OMB recently decided that the flight telerobotic service is no longer a candidate for third-party financing. Is that correct?

Mr. Rose. Yes, sir.

Senator Gore. What led to that decision—just a reality check?

Mr. Rose. Well, NASA has been investigating all of the seven private initiatives that were in the President's budget. As to the feasibility, the desirability, and what have you, NASA concluded that the FTS system just did not lend itself to this type. It would not work. And we so were able to convince the OMB of this.

Senator Gore. Any of the other private sector financing candidates taken off the list?

Mr. Rose. No, not at the present moment. They are all, and if you would like, we will let——

Senator Gore. What about the observational instruments laboratory at the JPL?

Mr. Rose. That is not off the list, but it is——

Senator Gore. It should be, should it not?

Mr. Rose. It should not—let me refer this question to Billy McGarvey, if I can, because he is in charge of our facilities and I think he can give you a better answer.

Mr. McGarvey. Senator Gore, it is not off of the privatization list as such. But in view of the unique nature of the facility at the jet propulsion lab, and the fact that California Institute of Technology is the operator and maintainer of the lab for us and has been for a number of years—when we pursued it, we came to the conclusion that it was not viable to share that facility with industry. That we were putting the university in direct competition with industry in the laboratory, overseeing certain projects of which they were responsible for.

So at the moment we have backed away from trying to finance it, or through a private investment of the private sector, and are looking to the California Institute of Technology to come forth with a proposal that would be mutually beneficial to both NASA and to the taxpayers, and to the Institute of Technology.

Senator Gore. So you are agreeing that it is kind of silly to think that a profitmaking corporation is going to be involved, and now you are looking for a good will donation?

Mr. McGarvey. No, sir, not a good will donation, but a participation by Cal Tech, similar to a previous facility that was built in 1985 that you may not be aware of. But we built a central engineering building at JPL, which Cal Tech Institute of Technology financed the construction, did the design and construction. And through their contract, we have amortized that investment, or will have amortized it fully within a 10-year period.

And it was cost effective, because of a large number of lease facilities that we had to lease off site in order to house the work force to do the work at the jet propulsion lab.

Senator **Gore**. All right. I will come back to this. My time has expired.

I do want to note for the record that Chairman Hollings and I wrote a letter to NASA on March the 10th of this year, advising that in our opinion, if the committee were to consider these private sector financing proposals, it would have to be convinced, one, that the private sector were willing to make an equity investment and there was a net cost savings to the federal government.

Or two, there were an overriding national interest.

According to NASA's own internal analysis, the private party must retain at least a 20-percent ownership of the proposed facility to meet this standard. Well, I will come back to this a little bit later on. But I think that we have got to take a new look at several of these other items and be realistic about it, as OMB apparently has done with the telerobotic servicer.

Senator Kasten.

Senator **Kasten**. Mr. Chairman, thank you.

Mr. Rose, you agree with what the Chairman said with regard to the kind of shifting strategy over time in terms of the overall direction of the commercialization of the space program—is that right?

Mr. **Rose**. That is correct.

Senator **Kasten**. To what degree has this shifting strategy over time been the result of funding questions, dollars, support, whatever. I am interested in issues regarding the difficulty of competing with foreign countries subsidizing and we all know they are.

In your testimony you have talked about our government participation with words like "strong government support," or you used "cooperative ways."

The fact is that if we are going to be competitive, we are going to have to be in this market place and balance the government support for domestic companies with what we see coming from other countries.

Is this the problem? Is this why this strategy has been kind of going up and down? Is it primarily being driven by the fact that we still are not sure what kind of a real long-term commitment, either the Republican or the Democratic administrations are willing to give to commercialization in space?

Mr. **Rose**. I would say that in my opinion, and having been with it from the industry side, as well as now in the government side, the—I think the problem has been—is that historically in the last 40 or 50 years, anyway, industry and government relations, or how to go about something—we have not come up with a method, because it is different.

If we say the government should help industry, there are those that will tell you that is taboo. The government will not help industry. Industry—when there is something to do and it makes sense to do it commercially, industry will go do it by itself. It does not need government help. That is probably very true if you are not in competition. You can afford the time luxury of letting it just happen that way.

But we are in competition because the Europeans and the Japanese look at high technology as their future. Space is high technology. Their government is heavily involved in making sure that high technological things get developed and into their industries.

And I am saying I think our problem with the policy has been we do not know how we want to do that yet. How do we want to get the government involved, and industry involved, working together.

And to that end, what little—what I am doing is trying to come up with something that I can have tangibly to present to you and everybody else that says, "This is what we ought to do in this area. These are the things we ought to do." Then I think policy can be made and I think stability can be gained.

Senator KASTEN. Then my sense is right. You are not quite sure that today you have got that mix. I mean, we could look around and we can see——

Mr. ROSE. I think we are very close.

Senator KASTEN. Well, you can see a government decision and a policy in terms of working with the government here in this country that turned out not to work out very well. That was synfuels.

You could look at a government decision in France and England that was made to get caught up to our leadership in aircraft. And now we have got the air bus and they are still being subsidized, but they are in the business.

Mr. ROSE. That is correct.

Senator KASTEN. And you can look at examples in which we have done this, but I sense we do not have a clear understanding of exactly what the U.S. Government commitment is going to be in terms of providing the money on the one hand, and then an understanding of what the commitment of the U.S. government is going to be as being a consistent customer you can count on.

Mr. ROSE. That is our suggestion.

Senator KASTEN. I sense there are an awful lot of people in this business that are saying, "I am happy to invest X number of dollars, if I am sure they are, in fact, going to buy ten of them with the schedule that they are talking about today." But I am worried that either the Congress, or OMB, or somebody at NASA is going to say, "We do not want ten, we want three, but we want them at the same cost that you were going to give us ten."

"And we have a hard time raising capital if we are not sure if we are going to have three, or if we are going to have ten," says the business executive. Am I right?

Mr. ROSE. You are absolutely right. I think every survey that has been conducted, people conclude the government is not a very good customer.

And that is why one of our strategies is to try to get us out of being a direct customer, but being—using the infrastructure and transportation world to help support the developing companies that want to do products. And make it so that we are letting the private world drive what is being required, and we simply help it. And I think that is the strategy that I think makes sense, and we have the mechanisms in place to make that type of strategy go.

The other issue that goes back, and it does go back for some years. I remember we have testified before Congress on occasions back in the late 1970's, early 1980's, relating to space commercial issues and said, "The government has never even stood up and said, 'We will make sure that there is a transportation system that will support commercial endeavors.' "

These products we are talking about developing—these pharmaceuticals, these crystals, these glass—all of this wonderful, new markets that are going to happen, and they will happen. They might take 10 to 14 years to develop.

Are we going to have a transportation system that can support that type of development? Will the government insist—sure that there will be.

Because some of these systems are going to need—they need the shuttle. They need other types of transportation, and we have never had those types of commitments.

So industry is leary of government's—how government is going to support them. And especially if they are putting in monies today that it might take some years before there is any pay back to them.

Senator KASTEN. Let me take the next step. We talked about the U.S. government as being a customer. It is clear to me that if we are, in fact, going to make a difference in this area, it is not going to only be the government of the United States of America that is going to have to be a customer. It is going to have to be governments of a number of other countries in the developed world.

What kinds of experience do you have in terms of selling different kinds of commercial space projects to other governments? Are they fencing out U.S. products in order to continue to have their products go? Are they protecting their own industries because they are making such significant investments in their own industries, and how do you look at the international market for sales of the kinds of products and space-related goods that you are in the process of producing?

Mr. ROSE. Well, I think the international markets—let us look at pharmaceuticals. It is like any other pharmaceutical if you can produce an alpha antitrypsin or you can produce erythropoietin, you can produce any of these well known hormones that are emerging and coming into being, there is a world market for it. And these companies, our companies operate on a world market.

I think some of the more interesting markets that might be required from an infrastructural or the infrastructure markets, let us take Spacehab, for instance, which is a company that is emerging to develop a carrier for the shuttle that will—the one thing we have in this country, we have got all the assets. If we just put them together, we can be first without any question in capitalizing on commercial space because we have got the transportation systems, we have got the shuttle, we are going to have a space station, we are going to have all of the ingredients, and we have got some 128 companies now working to make products, and we have got a bunch of infrastructure companies wanting to do business. If we put them together, you have got all the ingredients.

The Europeans and Japanese do not have access. They need access to space to do the research. They do not have it. They have to get it from us. Now, they will buy space on Spacehab. And so Spacehab has a customer.

In the Federal Republic of West Germany they have—the Japanese government will buy space for their companies. And if we do not buy some similar space to make sure that we get our companies and the CCDS's flying in space, they are going to be flying on our carriers, infrastructure carriers, and our market people are sitting down here waiting with some additional space to materialize in the mid deck of the orbiter.

So, the point is we have got to work the whole issue. We have got to work it as a business, and that business is we have got to couple our market developments with our infrastructure and our transportation, and we will beat the world. But we have got to do it.

Senator KASTEN. Mr. Chairman, thank you.

Senator GORE. Thank you.

Senator Robb.

Senator ROBB. Thank you, Mr. Chairman. I am sorry I was not here for your opening statement, and I must tell you that the testimony to date is—I cannot say whether it is encouraging or unsettling at this point.

I am curious with respect to some of the potential offshore development first in terms of launch capacity or whatever, we see a lot of technology that is going overseas. You have got a number of joint ventures that are already indicated in some of the companies here. How likely is it that they will give up for whatever reason on some of our potential and move offshore with some of the technology that has already been going overseas to date.

Mr. ROSE. I am not quite certain, Senator, that I understand the question precisely. What is going offshore?

Senator ROBB. Well, in terms of so much of the advanced technology is moving offshore and the very fact that we are having whatever start-up difficulties today in getting some of our commercialization off the ground, what is the likelihood that some of our current joint venture partners are going to pursue options with one of the other countries that we are dealing with?

Mr. ROSE. We already have a few of those who will be flying things on the Russian MIR, for instance, but I do not see a whole lot of that as long as we provide access. If our program provides the proper access, there is no reason for our technological developing companies, the companies that are developing the technologies that will need to go overseas.

Our centers for the commercial development of space, there are some advantage in their minds in particular cases to have industries from Europe work with us because they bring some technology to the marketplace or to the table that we could benefit from. So, I think that in fact our new advisory committee is going to recommend that we do a study to make sure we understand where we should compete and where we should cooperate as we work in this developing field.

But unless we do provide the necessary capacity to get into space is that private companies in this country will look overseas.

The only place where manned involvement is still available right now is in Russia, and we do have a company in this country who is going to do some protein crystal work with the MIR. The European companies, the French, the Germans, the others, they are all beginning to take advantage of the MIR system, and so some of our allies are doing much more of that than they are in this country.

Senator ROBB. With respect to the CCDS's—and there are currently 16 I think you indicated——

Mr. ROSE. Yes.

Senator ROBB. And you indicate those were mostly industry driven, I think, in terms of the establishment. What is the government's role in acknowledging, accrediting, accepting, whatever the case may be of some of these CCDS's and is there an essentially unlimited potential for the establishment of additional CCDS's?

Mr. ROSE. Yes. The answer to your question is yes to all of them, I think. First, the CCDS's are competed. I mean, they were selected under competitive conditions. The things that they propose to fly.

Senator ROBB. Who makes the selection?

Mr. ROSE. NASA did.

Senator ROBB. On the basis of an established competition?

Mr. ROSE. Yes, established rules and regulations for competition. In addition, we have established screening procedures so that the types of things that they propose doing meet certain criteria that we have established as it relates to getting aboard any carrier to fly. We want to make sure we understand the industry involvement and what the centers are doing, the importance of this technology, the type of product it might lead to.

And so, we do have a screening and a prioritization procedure. As I said, since they have been selected competitively, industry is driving the technology. We do have regular management council meeting with each one of the directors of the centers every three months.

It is a very cohesive, hardworking group of people that I think are making tremendous progress, and they are doing some outstanding work. In fact, I forgot to mention that the University of Alabama Birmingham's work in crystallography will be produced and will be written up in Science Magazine, the most prestigious—one of the most prestigious magazines.

There is no question the crystals grown in space are much better in resolution and in self-ordering than anything that can be done on the ground, and that has now been proved by the scientific community as such.

The 3M Corporation has found a new material that is totally different from anything, and they verified it with anything that has been done on the ground to date. In fact, it is a whole new look at how atoms order themselves in different materials.

And so it would appear—and they are coming out with the first space patent on a material that is totally unique to space.

So, we believe it is the right approach simply because you are tying industry and academia and you see, with all the strengths you have in your universities now, you are getting the industry saying these are the areas I would like to see you pursue because I am interested in those areas for my own business's point of view of where we would like to strategize and go.

Therefore, as these understandings are uncovered by testing and space and comparing things on the ground, these differences are going to translate into a product ultimately we believe. And industry is right there to pick it up and carry it because it is part of their interest.

Senator ROBB. Talking about strings, is there any legislative role in this process after the initial authorization over and above the oversight role in terms of individual projects or applications or launchers, whatever the case may be?

Mr. ROSE. No, sir.

Senator ROBB. Thank you, Mr. Chairman.

Senator GORE. Thank you.

Senator Lott.

Senator LOTT. Thank you, Mr. Chairman, and thank you again, Mr. Rose, for your being here today and for your efforts. I am pleased that we have got an administrator in this area that has a background in industry, and I feel like that will be very helpful as you try to provide leadership and direction in this commercialization area in the future.

I think it is important that we have adequate funds for these commercialization programs.

One of the experiences I had several years ago when I was in the other body on the Merchant Marine and Fisheries Committee—it always concerned me that the National Marine Fisheries was very much involved in research and theory and developing maritime laws and things like that, but there was never any ability to transfer the results of that research and all the information we had in the National Marine Fisheries to the private sector, the people out there actually fishing, and that is my point here again today.

I think we have got to be careful and we have got to be aggressive in trying to get the knowledge you have and the ability we have in NASA into the private sector. And so, that is why I put a lot of emphasis on the commercialization, and I worry that we put, instead, too much emphasis on the research side. So, that is a preface to some questions I would like to ask you.

First of all, what is your feeling about the success of the Centers for Commercial Development of Space as opposed to the normal government procurement process?

Mr. ROSE. I think that—I think I came close to answering that just with Senator Robb.

This country for quite a while, it was the industry—in fact, as industry I remember very distinctly we had our own research laboratories, we did our thing.

Occasionally you would read something that was happening in academia in certain select fields, but for a long time in this country it was—the norm was that the academic community did their own thing. Scientific research, they normally had their grants from people like NIH, other government offices, to do the type of research that they wanted to carry out.

I think that is one of the reasons that we have been caught up with technologically because our industries were not a part, and the two of them were not working together.

I think every blue ribbon committee that is studying things like superconductivity and every other area of concern in this country are coming up with the recommendations that we need to have consortia, universities and industries all working together.

The CCDS's, the centers for the commercial development of space are consortia of universities, industry and government working in a cooperative way in applied technology. That will lead to an application. That is a difference in basic technology and applied technology.

Applied technology is something you say if I can do this, then I can maybe produce that. And I think you are hitting at that. So, the CCDS's are more in tune to those types of technologies that can lead to applications and industry being a party to it is already involved.

Senator LOTT. I think the answer is then, it has not been particularly successful, but you think maybe we are moving into a period where it can be more successful and we can get some results?

Mr. ROSE. I do not think there is any question about it.

Senator LOTT. Let us talk about the small business innovation research programs. As I have talked with you about this and looked at the program, it sounds awfully bureaucratic to me, phase I, phase II, phase III. Come on, I mean, can we not eliminate one phase?

Mr. ROSE. The SBIR program?

Senator LOTT. Yes.

Mr. ROSE. We are looking at——

Senator GORE. If the Senator would yield, I happen to think that program was very well authored and written.

Senator LOTT. I am sure it was authored and written well, but I think the application and the regulations and the way it has been carried out could be improved upon.

Senator GORE. That is a theoretical possibility I would concede.

Mr. ROSE. Let me just—maybe you could turn to page 9 in the little handouts. It is a summary of the NASA SBIR program because I think, Senator Gore, this program has been in existence since 1983, and so we are really just beginning to understand the—what it can do or what has happened, and it is from this information that we can now go back, Senator Lott, and begin to figure how can we improve it.

There has been a steady progressive program that is getting the small businesses involved. You can see from the 1983, we had 977 proposals for phase I. Last year we had 2,379.

The phase II's we now have—we have gone from 92 proposals to the 1987 179.

Senator LOTT. Let me interrupt you there, if I could. You know that is great, but then five years is a long time, and so I do not want to give a whole lot of accolades for what has happened in 5 years.

Well, let me just ask you this. How many of the SBIR projects relative to cumulative phase I awards have led to actual commercialization in phase III of the program in the past 3 years or in the last year?

Mr. ROSE. Okay, we just had a survey done on that this past year of the first 78 phase II programs that were completed. I will give you two statistics. Thirty-nine of those completed phase II SBIR programs have gone into direct application within NASA, 18 of them have already found their way into the commercial use. So, that is the data base we are beginning with.

You see, the phase IIs are just ending. We have just had enough time to go from phase I through a phase II selection, and so the original first 78 phase IIs. Twenty-five percent of them have already found commercial application.

Now, one I think we are going to find out is we do need pilot work to see if we cannot improve the selection process so that we can include commercial potential as also a major criteria, and what I am saying is we are now learning what we ought to be doing to make it even better.

Senator LOTT. Mr. Chairman, probably my time has expired. Could I go ahead and ask a couple of more questions on this round?

Senator GORE. Sure.

Senator LOTT. I worry that in the past maybe there has been too much emphasis placed on the research side. Even in this SBIR program as opposed to the commercial potential are we beginning to shift that emphasis a little bit?

Mr. ROSE. We are beginning to take a very strong look at ways, yes. I think we are going to——

Senator LOTT. It is natural for the people at NASA and the people you work with to look at the research side, and I think it is going to take an effort to force more emphasis on the commercialization side.

Mr. ROSE. Well, we are setting up a pilot operation at the Stennis center in your home state, by the way.

Senator LOTT. That is extremely interesting and appreciated, I assure you.

Mr. ROSE. To begin the new pilot work to see how we can do a better job of trying to satisfy our centers who are looking for research, but it can also be research as well as something that could ultimately have commercial application.

Now, I am not at all convinced that you said maybe we should not have a I and a II and a III. Maybe the step we have now called II is not enough. Maybe there are a lot of things hanging there that we have not been able to bridge yet to get them into a commercial state. That maybe as this program evolves, we might need to put more money and more time to give it more maturity so that it has a better chance of having a commercial application. They are things we are going to study this year, and this pilot program is going to help us do that.

Senator LOTT. Do you give consideration to geographic distribution and do you give consideration to unemployment status in various geographical areas in your awards or not?

Mr. ROSE. I do not think that that is a written criteria.

Senator LOTT. Either of those?

Mr. ROSE. Either of those are written criteria. It is based on people all over the United States proposing against topics that have been developed and approved by the various centers, the nine NASA centers that participate in the program.

It is quite possible—obviously there are certain geographical areas. Yet, because of their nearness to some of the centers and what have you could very easily be better prepared to write proposals that are acceptable.

Senator LOTT. I do hope you will give some consideration to trying to give all the areas a shot at these programs. If they become too focused and that could include our region, then we are going to run into trouble with people in other areas that would like to be able to participate in them. And so I hope some consideration will be given to that.

Mr. ROSE. Well, again, I think we do have 40 states participating. That is still 10 that are not, and in some of those 40 they are really just one or two contracts.

A lot of it depends upon the nature of the type of businesses that are in these states, but I do think we should find ways to try to encourage these places that we are not seeing that much response from to work within these states do find methods of trying to get their small businesses geared up to be more competitive.

Senator LOTT. My last question, Mr. Chairman, for now. You are asking for a budget increase of 36 percent for the Office of Commercial Programs. Are you going to use this to try to expand the private sector participants or are you going to use it to try to advance the management of existing programs or exactly what are you going to do with these extra funds if you get them?

Mr. ROSE. All right, let me speak to that. It might not be known by this committee, but we really—last year we lost nearly $12 million out of our budget due to House appropriations cut and in reaching their agreements, the Senate put it back in, and then it fell out again in the committee, and so we have had to tighten our belt this year. The actual growth is just a minor growth from where—from the 1988 runout. It is just a minor growth, and it is almost just enough to cover inflation between what we should have been spending this year and next year, and so we have had to stop many applications programs.

In the TEU program, we have had to cut back in other areas to get through fiscal 1989. So, really, I think I would like to put that on the record that we are not jumping. Actually we are marking time and pulling our belts in until we could get through this year, and we hope that will not happen to us again in the 1990 budget.

Senator LOTT. Thank you very much, Mr. Rose. I am looking forward to working with you and supporting these programs. I think they are very important.

Mr. ROSE. Thank you, Senator.

Senator GORE. Thank you very much. I appreciate your questions. When I chaired the Science Investigation Subcommittee on the House side I had the opportunity to work a good deal on the SBIR program and indeed to help author it. Mr. Rose, I think you have done a better job in the last 2 years with it. I think that there does need to be some improvement, but I think the last couple of years it has improved somewhat.

In your testimony, Mr. Rose, you discussed the AIAA draft strategic planning report. I wonder whether or not you agree with a principal premise of this report that we need specific goals to aim at and to use in measuring our progress. Let me quote from that draft report:

"Specific objectives need to be defined against which performance can be measured. Comparisons with the development and growth of similar high technology industries such as aviation or computers and information processing suggest that by meeting the following objectives the six areas of U.S. commercial space industry identified below could by 2020 generate substantial annual revenue to the United States and could garner a major share of the free world commercial market."

Then they go on to suggest some specific goals and objectives as ways of measuring whether or not we are doing a good job. Do you agree with that premise?

Mr. ROSE. I certainly do. The AIAA, this study and this work that they did was done at my direction and at our office's direction because we believe strongly that we need goals and objectives from the industry standpoint of view where these industries might be if we are going to adequately put in place the mechanisms and the initiatives that will help meet those goals. So without knowing where we might be it is hard to defend what you are doing and saying I have to do these. These things are necessary. This is what we lose if we do not do it.

So they were chartered to hopefully provide us something tangible that we could use in our developing strategic plan and that is exactly where the input from this report will be. These inputs—this report, incidentally has been a major element in the review by our new Advisory Committee. They have used this report that you are talking about in forming some of their conclusions and recommendations.

Senator GORE. All right. Very good. Let me come back to the third party financing question that I talked about before. You said that there are seven projects on the list of projects where NASA is assuming third party financing. You also said that when that list was put together and the original proposal was made, it was assumed that the private sector was willing to invest in these projects and to put capital at risk.

It also was assumed that such proposals would lower the cost to the government because these would be multi-purpose, or shared-use facilities. Are these still the assumptions, and does NASA make a specific assumption about the percentage of private sector equity and shared use to assure a cost-effective proposal?

Mr. ROSE. Billy, why do you not answer that?

Mr. MCGARVEY. I think that the answer to the overall question, Senator Gore, is yes, that we are pursuing—and I am speaking now to the ground facilities and not to the flight hardware, but to the ground facilities—that in order to be cost-effective there must be some joint use and joint sharing of it and to have an investor willing to take an equity in the facility.

Early—before these were put out on the market to test the interest by the private sector to see if there was an interest in pursuing them, we did a rough cut sensitivity analysis along the A-104 OMB guidelines and it determined in general, depending on the project, that you had to retain about a 20 percent equity in order for it to be cost-effective to the government and we still believe that that is the situation today.

If I could address a couple of those, the Neutral Buoyancy Laboratory down at the Johnson Space Center, which is one of the facilities in support of the space station development; the draft RFP to go to industry for comments by industry and encouraging them to propose innovative proposals for cost-sharing and the joint use of them, that is in the process of final preparation at this point and we expect to release that draft RFP for comment by industry this week, before the end of the week.

The space station processing facility at the Kennedy Space Center for processing the structural elements and the modules themselves, or the station, we have drafted—put together the draft RFP and that was released last week.

It is out on the market now for comments by industry and we expect those back within a 30-day period, so by early July we will have had an opportunity to evaluate the responses on those and to determine at that point in time, again by running a financial analysis along the OMB guidelines, the A-104 procedures, the title of that circular, for doing that.

At that point in time we will reevaluate those and see if we have any effective proposals that make sense from cost-sharing and cost-effectiveness to the taxpayer and to the government to do that.

Prior to arriving at a decision to go with an RFP we fully intend to come back to the congressional Committees to update you on where we are and to seek your concurrence in proceeding with an RFP—a formal RFP—at that point if the data supports it.

Mr. **Frankel**. Mr. Chairman, Mr. McGarvey is exactly right that in our analysis we came up with that approximately 20 percent number. That assumes that there are no other types of offsets. It does not have to be a 20-percent use.

For instance, in the central engineering building that Mr. McGarvey talked about earlier we felt that that made sense economically because there were other costs that were avoided in terms of off-site leases which you would avoid which therefore made the 100-percent financing economically sensible to the government.

Should there be other types of participation, such as savings having to do with program savings or savings in leases, or things like that, you could have a situation where it would make sense to go ahead with a privately financed deal, even without any participation. However, with the ones that we are talking about here we have talked about specifically with respect to that kind of participation on a 20-percent equity interest.

Senator **Gore**. Well, let me pursue that in the context of the extended duration orbiter. Is NASA considering, or willing to agree to a take or pay contract that guarantees the contractor the cost of developing the EDO and then allow the contractor to make a profit by leasing it to foreign or commercial customers. Is that under discussion?

Mr. **Frankel**. Yes, there is. We do not have a proposal, a firm proposal in that area. There is a suggestion that we may be able to save money by allowing the contractor to produce that, or part of it, with their own funds and then they would only receive a partial pay-back with no profit for that effort and then get a payment any time there is a foreign or commercial use of the EDO. To the extent that the government would not be paying any profit on that, it may be, if the proposal was appropriate, in the interests of the government financially to accept that. But we have not gotten a firm proposal with numbers that can be analyzed yet.

Senator **Gore**. Well, we would like to be kept up to date on these proposals and we are going to be following them very closely. We will have other questions in writing for the record.

I would continue if we had time to do the give-and-take, but we are really going to have to move on.

Senator **Lott**. Mr. Chairman, I would like to ask just one or two other questions if I could and I will be brief, I promise.

Again on the small business involvement, so much of the commercial space industry, it is tremendously capital-intensive and that creates, I think obviously, barriers for some of the innovation and some of the involvement that you can get from small business. How are we going to help small business in their management and get over these hurdles to be able to participate?

Mr. **Rose**. Senator, what we are trying to—one strategy we have got to do that is, we are encouraging our CCDS partners who, there are some 16 of them plus, you know, they have got a number of universities and a number of industry partnerships going, to use the SBIR program to help as a method of getting—because some of these CCDSs are spinning off small businesses. Of course, one of them is—we have a number in the remote sensing area working with small businesses. So we are having workshops and seminars to help train these people and tell them how they can use the SBIR program.

Now, the SBIR program, they should be working on things that will be bridged. The CCDSs can now bridge them into an ultimate application, so we are using not only our CCDSs but we are beginning to use our industrial application centers associated with the technology utilization programs to do similar things.

Senator **Lott**. I understand that your SBIR program does not provide funding for management or marketing of the SBIR programs. Is that correct?

Mr. **Rose**. That is one of the problems we face in the sense that it is——

Senator **Lott**. You know, you get the funds by, in effect, borrowing or taxing other programs. I wonder if you think maybe it would be a good idea and could produce greater commercial output if in Phase 3, 1 or 2 percent of the SBIR budget could be set aside for management and promotion?

Mr. **Rose**. I definitely agree with that, because it is difficult sometimes to, as the program is growing, to take moneys from other sources just to pay for the administration and I think the program can be better administered if we could set aside a small amount and let it—percentwise, so as the program is growing in dollars, that also we have got more of an absolute number of dollars to spend on administering it and doing it more efficiently and effectively.

Senator **Lott**. That is something you could do internally. We do not need to act on that, do we?

Mr. **Rose**. I do not know. Our general counsel is here right now. We tend to interpret the rule that says that is not legal. I do not know. Could you comment on that, Ed?

Mr. **Frankel**. I did not look at that statutory language before I came today, but I think it has been interpreted so far to say that the program requires us to spend a certain amount of money on—

or, send it out to the small businesses. We certainly can look at it again and see if there would be a way to claim that by taking part of it and spending it internally we in fact were helping to do that. I am not sure about the language.

Senator **Lott**. Thank you, Mr. Chairman.

Senator **Gore**. You are most welcome, and Mr. Rose and your colleagues, the subcommittee appreciates your presence and participation here this morning. Thank you very much.

Mr. **Rose**. Thank you, Senator.

Senator **Gore**. We will work with you closely in the weeks and months ahead.

[The following information was subsequently received for the record:]

Responses to written questions submitted by Chrm. Gore.

International Cooperation and Competition

The NASA Commercial Programs Advisory Committee's (CPAC) Subcommittee on International Competition and Cooperation recently noted that:

"In earlier days, the U.S. could proceed at its own pace in space pursuits. Because it dominated the field, it could achieve desired goals within fiscal and political constraints, with bureaucratic inefficiencies, accommodating new technologies as they emerged.

"That is no longer the case. The development of foreign commercial space capabilities (and aspirations) is the central issue to the work of CPAC.

"It's straightforward. We either change our modus operandi, or we'll be an also-ran in the commercial space market."

Question 1: Mr. Rose, what model and what level of participation are being proposed by the CPAC? A model with "heavy," "moderate" or "minimal" government participation?

Answer 1: The Commercial Programs Advisory Committee's (CPAC) proposed model incorporates a moderate level of government participation which maintains a balance between fiscal pressures and the need to provide the support to private industry necessary for the U.S. to remain competitive in the international commercial space market.

While moderate government involvement on the macro level, including stable, supportive policy, should be a continuum, the specific level of support the government should provide to the development of private sector space activities depends on the state of maturity of each commercial space market sector, and of specific market segments within each sector.

Question 2: And, what are the pluses and minuses of each of these models? Which of these will best guarantee "market share?"

Answer 2: Due to the increasingly international nature of the commercial space market and the significant levels of support provided to foreign competitors by their respective governments, a minimal level of support is insufficient for U.S. firms to remain competitive and retain a maximum share of the global market.

At the other extreme, a heavy level of government participation would lead to a substantial change in the risk/reward perception and attitudes of U.S. investors which would mean a sub-optimal allocation of capital resources. In short, investors might be led to invest in projects which did not hold the greatest market potential, which over the long term would also deter U.S. competitiveness relative to international markets.

In order to achieve maximum "market share" the Government should assume a positive and active role of moderate support on the macro level. In doing so, appropriate roles must be defined in order for commercial interests to plan accordingly. Roles must be defined swiftly and clearly for an effective, more cooperative government-industry relationship. The roles of individual agencies must also be defined, including jurisdictions and relations with industry. Particular emphasis should be placed on avoiding conflicting and overlapping agency jurisdictions and orientations.

Question 3: To what extent does the current budget deficit influence the thinking of the members of the CPAC and the proposed remedy? And should the U.S. subsidize its industries, directly and indirectly, to remain competitive with subsidized foreign competitors or only when there are market failures?

Answer 3: The current budget deficit is an influencing factor. In today's budget environment, it may not be feasible to pursue market leadership in every space sector. Strategic decisions are needed on which markets to support and develop. The decision criteria are both strategic and economic. Areas to pursue must be selected based on their strategic value and ability to develop private sector competitiveness with minimal budget impact.

CPAC has made a number of recommendations to promote market position which do not require subsidies. These include ensuring that intellectual property is adequately covered internationally, unified policy and procedures for technology transfer controls, and identification of foreign nontariff trade barriers and negotiations with other countries for equal market access.

Success Story of Commercial Program

Too often, the focus of policies are the failures -- not the successes.

Question 4: Therefore, would you please give the Subcommittee a few of your Office's program highlights of the last year including the Memorandum of Agreement with the University Corporation for Atmospheric Research (UCAR) for use of External Tanks, and the Space Systems Development Agreement with SPACEHAB, etc.?

Answer 4: The following items are a few of the Office of Commercial Program's program highlights of the last year:

a. A Memorandum of Agreement was signed for NASA support of commercial expendable launch vehicles with McDonnell Douglas, September 1988, with Martin Marietta, October 1988, and with LTV Missiles and Electronics Group, November 1988. We recently signed a support agreement with Conatec, Inc. for expendable vehicle launch support.

b. We signed a Memorandum of Agreement with the University Corporation for Atmospheric Research for sub-orbital use of up to five expended shuttle external tanks in December 1988.

c. A Space Systems Development Agreement was signed with SPACEHAB, Inc. for six flights of the SPACEHAB Middeck Augmentation Module in August 1988.

Question 5: Does NASA have any usage requirements for the SPACEHAB or the UCAR External Tank facilities? Has NASA entered into any agreement to use these facilities, or has NASA considered bartering usage of these facilities for a lower space shuttle launch price?

Answer 5: Under the auspices of OCP, flight requirements for commercial development programs have been compared with projections of flight opportunities available through the early 1990's. It has been determined that otherwise unsatisfied requirements could fill more than half of the SPACEHAB-01 flight, and a significant portion of follow-on SPACEHAB flights. However, NASA has made no formal decision to pursue the lease of SPACEHAB and no funds to do so are included in our FY 1990 budget.

NASA has not identified a specific need for the external tank facilities at this time. As the commercial external tank project matures, NASA will review its requirements in terms of an overall flight plan.

As for any measure of "barter" arrangements, there have been preliminary inquiries of in-kind exchanges of value such as Shuttle flight for access to SPACEHAB modules. However, such discussions have been only in the exploratory stage. There is presently no commitment for a barter arrangement.

Any NASA requirement for additional flight capability would follow an open and competitive procurement process unless justification for sole source was approved.

Question 6: What efforts has your office made to use the CCDS program as a catalyst for newly created space transportation and hardware firms? Do you intend to augment this program, and have you considered a Space Transportation Voucher System for this purpose as discussed in the Reagan Space Policy?

Answer 6: During this past year the Centers for the Commercial Development of Space (CCDS) program has made several inroads to stimulating private sector initiatives leading to the commercial use of space. Some significant examples are:

a. The University of Alabama-Huntsville CCDS has developed a commercial sounding rocket flight for the CCDS program. This stimulated competition in the small expendable launch vehicle industry as well as small business space-related hardware development. The project was so successful and effective that we are planning to expand the program to two to four flights a year depending upon our ability to augment the program as an Office of Commercial Programs "pilot project."

b. The University of Houston CCDS is developing a "Wake Shield Facility" to develop a test bed for growing thin-film crystalline materials using the high quality vacuum of space. The facility development is providing a true catalyst for several small (non-aerospace) businesses to enter into the commercial space hardware development field. This is a "pilot project" that will serve as a model to show the government and small businesses how they can participate in the new frontier of space and save taxpayers millions of dollars.

c. The Auburn University CCDS has already spun-off a product for terrestrial use while studying a space power development concept for Space Station Freedom. One of their consortia partners has developed a new capacitor for charging power supplies that will have applications to lasers, x-ray and E-beam machines, and many other industrial applications. It was less than a year from concept to product marketing, and the first power supply device has been sold. The significance of this is two-fold: an early spin-off and a new commitment from an old line company to begin developing space-oriented hardware. This CCDS is proposing a "pilot project" that will have enormous impact on heat generating and transfer requirements, and ultimately cooling and weight features of space electronics systems. This effort will definitely be a space hardware development catalyst if funded.

d. The University of Wisconsin-Madison CCDS has spun-off of a small business that is using their space developed technologies for "astroculture" which includes space station or space voyage food development concepts. The technology includes hardware development for plant growth, maintenance and lighting. Close working relationships with various consortium members are having a synergistic impact on the development of commercial space technologies.

In general, the Office of Commercial Programs plans to continue "pilot projects" through the commercial development of space and encourages them to be the catalyst for creating opportunities that will foster space transportation systems or space-related hardware.

With respect to President Reagan's Space Policy Presidential Directive I entitled "Voucher for Research Payloads," NASA, in conjunction with the Department of Transportation, performed a preliminary assessment of the proposed voucher program. The task team found no evidence of a reported backlog of payloads in storage that could be accommodated by existing expendable vehicle launch services. The team recommended that at present the voucher system is not applicable because existing payloads were "pre-engineered" for Shuttle, and to modify them for expendable launch vehicles would involve exorbitant costs.

Question 7: Besides the seven commercial proposals that you have outlined in your testimony, what other "commercial hardware or services" are being considered by NASA? For example, what is the status of the Boeing space station logistics module proposal?

Answer 7: The only "commercial hardware or services" NASA currently has under consideration were presented in my testimony in the form of seven potential joint endeavor agreements. The Boeing space station logistics module proposal has been reviewed by the Space Station Program Office. However, with recent changes in key officials, that proposal has been put on "hold" until new management can be thoroughly briefed.

Commercially Developed Space Facility

Question 8: On Friday, pursuant to Section 208 of Public Law 100-685, the Committee received a letter report from NASA on the National Research Council and National Academy of Public Administration reports on the proposed Commercially Developed Space Facility (CDSF). Mr. Rose, will this decision by NASA adversely affect space commercialization, and was this report approved by the National Space Council?

Answer 8: It is true that commercial payloads are not ready in the near term to use a CDSF type facility. The unique capabilities offered by the CDSF and other "free-flyer" concepts have not been a consideration in space flight payload planning. Therefore, there are fewer payloads identified as being specifically developed to use those capabilities than if the CDSF concept had been considered for planning purpose. Like any unique facility, once its capabilities are made known, new payloads and designs may be developed to exploit those capabilities.

We agree that the lack of a free-flying facility may not impact commercial development in the near term as indicated in the reports. However, with international competition having access to Eureka and other potential free-flyers in 1991, we may lose our competitive edge in many lucrative new fields. Access to space is absolutely essential to develop new applications and free-flyers clearly offer advantages for future long duration experiments.

Question 9: Will there be demand for a privately developed CDSF at some point in time if your program is successful?

Answer 9: Although our program is in its infancy, it has already achieved a high degree of success. There are strong indicators by our industrial scientists and technical managers that free-flyers or something similar to a CDSF will be needed to fully exploit the commercial use of space by the turn of the century.

Space Commercialization

For the last eight years there has been a lot of discussion about space commercialization, but I doubt you could find two Members of the Committee who agree as to what the term means.

Question 10: Mr. Rose, what is "space commercialization," and what is NASA's policy towards space commercialization? How does space commercialization differ from space privatization? And where are we right now with regard to developing a Bush Administration space commercialization policy and implementation plan?

Answer 10: Commercial development of space involves both commercialization and privatization efforts. The terms "commercialization" and "privatization" of space are frequently used interchangeably, although they have quite different meanings. As used at NASA, "commercialization" means encouraging and facilitating domestic private sector application of the products, knowledge, or services resulting or deriving from space activities, while "privatization" means shifting to the private sector the acquisition of goods or services required to conduct NASA programs.

NASA has played, and will continue to play, a major role in supporting the commercial development of space. The goal of the program is to increase private investment in space activities and the applications of aeronautics and space technology by reducing the technical, financial and institutional risks of doing business in space.

President Reagan's revised national space policy of February 1988 contained a 15-point commercial space initiative which NASA has supported. The newly reestablished National Space Council will review United States Space Policy, develop a strategy for national space activities and establish a process for developing and monitoring the implementation of national space policy and strategy.

Question 11: Does each Federal agency have its own clearly defined space commercialization program and implementation plan, and who is responsible for coordinating space commercialization activities in the Bush Administration?

Answer 11: Other agencies do have varying interests in space commercialization and some with specific responsibilities, such as DOT's Office of Commercial Space Transportation, have plans and programs to meet those responsibilities. The degree to which their interests, plans and programs are clearly defined is a question better addressed to them.

The National Space Council is playing a significant role in coordinating agency efforts on such issues as Landsat's commercial future. The Council is also preparing for a review of space policy. The timing of its consideration of commercialization policy is yet to be determined since the Council is in the start up phase of its operations.

Question 12: What role is your office playing in the review of space commercialization policy by the National Space Council? What role is NASA playing?

Answer 12: As evidenced by our role in the Landsat commercialization issue, NASA fully participates in the analysis and deliberations of the Space Council. NASA would also be fully involved in the Council's review of commercialization policy and NASA would, of course, seek the counsel of its Office of Commercial Programs.

Barriers and Goals

There have been many reports written that highlight the many barriers to space commercialization. In particular, these reports highlight inconsistency in federal policy, federal procurement policies, federal competition with private sector initiatives, etc.

Question 13: What efforts are being made to address the barriers to space commercialization, and are these barriers real or imaginary?

Answer 13: The barriers to entry into the commercial space market are very real and significant. Some of the more substantial barriers blocking U.S. industry are limited in expansion flight opportunities, the huge up front investment and extreme costs of doing business in space (including transportation and insurance costs), the traditional emphasis of U.S. industry on short term performance of investments versus the long pay back period of commercial space ventures, the high risks of success of commercial space ventures (these risks fall into several categories including: political, technical, schedule, contractual, market, and financial risk), and the lack of a level playing field internationally due to the large subsidies many foreign competitors receive from their respective governments. The Commercial Programs Advisory Committee is helping NASA address these and other issues.

Question 14: Would one be wrong if they said that the principal barriers to space commercialization are the lack of a market besides the federal government and excessive transportation/business costs-risks? What steps are you taking to correct this situation?

Answer 14: No, one would not be wrong to say that the lack of a market for space based products is due to the excessive costs and risks associated in developing, producing, and bringing to market commercial space products (including services and information). In fact, excessive costs of production would limit the market for virtually any industry where potential substitutes existed.

The following two programs are vehicles NASA has in place to help companies alleviate excessive costs, reduce risks, and develop markets:

> Joint Endeavor Agreements (JEA) - The JEA is a cooperative working arrangement with firms which have committed resources and are in active product development stages. These agreements provide such firms with access to NASA facilities and services in return for the right of NASA to use data or hardware emanating from these commercial research efforts for its own use.
>
> Centers for the Commercial Development of Space (CCDS) - For those firms not in a position to commit to long-term investment, NASA has established the CCDS Program. The CCDS's are a consortia of university, industry, and government involved in early research and testing stages of potentially viable products or services. The goal is to provide a three pronged approach of support where NASA provides financial backing during the applied technology phase, academia supports the R&D function, and industry places a bottom line market emphasis on development of new products.

In addition to these programs NASA's Office of Commercial Programs (OCP) has embarked on a number of initiatives to achieve the above mentioned goals. These initiatives include sponsored research, deferred payment agreements for launch services, procurement agreements for expendable launch vehicle services (ELV) expended shuttle external tanks, solicitation of proposals for space commercialization from private industry sources, development of management tools to assist corporate and CCDS managers in understanding the complexities of the commercial space environment, and studies to determine the impact of transportation costs on entry decisions by the private sector.

Commercial Space Infrastructure Policy

Question 15: In your statement you indicate that you have drafted a Commercial Space Infrastructure Policy, Criteria and Procedures document. What is the purpose of this document, and when will you be prepared to discuss its content with the Subcommittee?

Answer 15: The purpose of the Commercial Space Infrastructure Policy, Criteria and Procedures document is to create a framework for NASA to evaluate unsolicited commercial space infrastructure proposals from industry. I would be happy to discuss the contents of the document with the subcommittee at any time.

Question 16: Does this document outline NASA's use and procurement policy for commercial space infrastructure?

Answer 16: The document does not specify particular programs or projects which NASA will offer for commercial participation. It is directed toward the private sector's unsolicited proposals for commercial space infrastructure provision. It sets out NASA's general philosophy towards commercial participation in NASA programs, the criteria by which an unsolicited proposal will be evaluated and the procedure NASA uses to evaluate a proposal. On a case-by-case basis, NASA will announce opportunities for commercial participation.

This document concentrates on Space Act authority to negotiate an agreement with industry and does not detail procurement procedures.

Question 17: Does it assume the government should be the "primary" market for commercially developed infrastructure?

Answer 17: The criteria include a preference for proposals which have customers other than the government. Although in the near term, most, if not all, infrastructure ventures will need the government as the prime customer, the intent is to give preference to projects which demonstrate the highest potential for a fully commercial success.

NASA Technology Transfer Center

Question 18: At the Subcommittee's April 11th hearing on Space Science and Applications, the issue came up of establishing a NASA Technology Transfer Center (NTTC) at Wheeling College in West Virginia. Would you please give the Subcommittee the status of that initiative? What is the estimated cost? And does NASA support such an initiative?

Answer 18: The report of the conference of the Committee on Appropriations on the FY 1989 HUD-Independent Agencies Bill directed NASA to conduct a definition/design study with a five year cost estimated by February 1, 1989. The Office of Commercial Programs formed a team of national technology transfer experts to assist in the preliminary study and report.

The report was forwarded by NASA on February 7, 1989, to the Appropriations Committees of the House and Senate as directed. The estimated costs follow:

ESTIMATED TOTAL COST

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Operations	1095	2580	3430	4540	5525	17,170
Development	3900	6300	4350	3350	2600	20,500
	4995	8880	7780	7890	8125	37,670

ESTIMATED CONTRIBUTIONS AND REVENUES

Contributions	4995	8880	4350	3350	2600	24,175
Revenue	0	0	3430	4540	5525	13,485
	4995	8880	7780	7890	8125	37,670

Question 19: Where do you recommend that the Subcommittee fund this initiative, in the NASA Technology Utilization Account? Or in some other account?

Answer 19: We recommend that the Subcommittee fund this initiative in the Technology Utilization Account.

Senator GORE. Let me ask our next witness to come up to the table—Mrs. Stephanie Lee-Miller, Director of the Office of Commercial Space Transportation with the Department of Transportation.

Mrs. Lee-Miller, I understand this is your first appearance before the Senate and I would like to take the opportunity to welcome you to your new position and we are most pleased to have you come before us as a witness today.

The way this procedure operates, without objection we will put the entire text of your prepared, written statement into the record and if you could summarize your prepared statement we would appreciate it.

But before you go forward with your testimony, would you please introduce your colleagues at the witness table?

STATEMENT OF STEPHANIE LEE-MILLER, DIRECTOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, DEPARTMENT OF TRANSPORTATION, ACCOMPANIED BY GERALD MUSARRA, PROGRAM COUNSEL; AND NORMAN BOWLES, ASSOCIATE DIRECTOR FOR LICENSING PROGRAMS

Mrs. LEE-MILLER. Yes. Thank you for your welcome, Senator Gore. I would like to introduce, to my right, Gerald Musarra, who is the program counsel for the Office of Commercial Space Transportation and to my left, Norman Bowles, who is the associate director for the licensing program division.

Senator GORE. Very good. Welcome to both of you as well, and please proceed.

Mrs. LEE-MILLER. Mr. Chairman, members of the Subcommittee, thank you for the opportunity to discuss our fiscal year 1990 budget for OCST and also to address other issues affecting the American commercial space launch industry.

Senator Gore, as you indicated I am appearing before this Committee for the first time and I am in within the first two months of serving as Director of OCST. However, it is quite evident to me that the support that you and other Subcommittee members have given to the commercial launch initiative has been a key factor in the very real progress that has been made to date and real progress that we hope to see in the future.

We are beginning an exciting new chapter in the history of U.S. space endeavors and on behalf of Secretary Skinner and the Department of Transportation we would like to thank you for your support and indicate we are looking forward to continuing to work with you and the rest of the Congress.

On February 9, President Bush presented his budget initiatives to Congress and the nation. At that time he indicated that aggressive pursuit of our varied national objectives in space would be a high priority for him. In particular, he made it clear that the private sector must play an increasingly active, direct role in achieving these directives.

OCST is committed to working toward our part of this goal and I believe it can be done within the framework of a realistic and reasonable budget. That said, it bears emphasizing that with more than half a dozen U.S. firms conducting commercial launch activities and with foreign competition heating up on several fronts, our program must be properly funded in order for OCST to perform its oversight and guidance responsibilities effectively.

For fiscal year 1990 we are requesting a budget of $4.4 million. You indicated, Senator Gore, at the outset of this hearing that your interest is in hearing about an action plan and hearing what the agencies are planning to do to implement our mutual goals.

Our budget reflects our action plan for 1990. First, the major portion of our time and resources in OCST is focused on the continuing development and implementation of our regulatory program. Last year the office published final licensing regulations which provide the administrative framework for overseeing a broad range of launch activities that are being conducted or planned.

In meeting its mandate to license commercial launch activities to ensure that they are conducted as safely as possible, OCST is in the process of completing a baseline assessment of the ESMC range and working on baseline assessments of three other existing ranges—White Sands, Vandenberg, and Wallops Island flight facility.

Other analytical bases include a major comprehensive safety study report that we have issued, hazard analysis of commercial space transportation, and the Interagency Report on Orbital Debris Hazards. This information, along with activities in assessing and evaluating launch risks and inspecting launch sites, vehicles and payloads, enables OCST to meet its regulatory obligations and set appropriate insurance requirements.

OCST has also been working to develop appropriate investigation procedures which would apply in the event of an accident.

To date, OCST has issued launch licenses to three companies. These include McDonnell Douglas, Conatec and Space Services, Incorporated of America. We expect to act on at least six more license applications this year.

We have also been working to achieve prompt implementation of the 1988 Commercial Space Launch Act Amendments and I am happy to report to you that much progress has been made in all the significant areas addressed by the amendments.

Section 8 of the amendments directed OCST, in cooperation with Defense and NASA, to study ways to facilitate commercial use of U.S. launch facilities. This is our scheduling report and we expect to report the findings to Congress this month.

In the last several months we have spent a significant amount of time addressing issues associated with the provisions in the amendments pertaining to insurance and other liability related requirements.

We are happy to report that pursuant to the provisions of the amended act, we were able to establish insurance requirements for the SSI launch which was very successful and our first licensee, and the upcoming McDonnell Douglas launch which is scheduled for June 8th or 9th.

In addition, we are on our way to crafting appropriate insurance requirements for two other major launch firms—General Dynamics and Martin Marietta. Another very important focus involves the multifaceted area of international competition and I know this is a particular area of interest to you, Senator Gore.

The issues here encompass not only our efforts to further the Administration's and this Committee's common objective of securing a level playing field for U.S. firms, but also our efforts to ensure that U.S. firms can meet the challenge posed by new competitors like the People's Republic of China.

OCST was the first office in the Executive Branch to recognize the implications for U.S. commercial launch providers of the Chinese government's new role as a market competitor and our office was very active in the Administration to ensure that China's entry was conditioned by appropriate safeguards.

Also, in our office I have recently designated an internal task force to facilitate OCST's role in monitoring China's compliance with the Long March agreement provisions. DOT also serves as the lead agency in supporting the efforts of the U.S. Trade Representative's office to assess the utility of a formal trade arrangement with ESA and to develop appropriate trade principles.

In our fiscal 1990 budget, we are requesting $3.6 million to fund research program activities and $805,000 for administrative salaries and expenses. I will just hit a few of the high points in terms of where that money will go.

For safety research we are requesting $1.5 million to fund several projects which will include research on commercial launch operations and ranges, environmental safety, orbital safety and payload safety. We are also requesting $475,000 for support and management of space safety data. We are requesting $575,000 for continued licensing and enforcement operations.

In 1988, OCST reviewed six applications. In 1989 we expect up to nine and in 1990 we anticipate as many as 20 license applications.

We are also requesting $400,000 to track and maintain information on the competition, on the competitive position of U.S. industry. There is also a request for research-related salaries and administrative costs and $50,000 to facilitate response to the industry.

Mr. Chairman, the Congress and the Administration are allied with American business in the development of a dynamic new industry—the commercial launch industry. We stand jointly on the crest of a wave of aggressive, imaginative activity on the part of a diverse group of companies. This activity may well contribute much to our future well-being and growth and productivity as a nation for many years to come.

However, moving boldly into the future is going to require a firm and consistent policy from the government. President Bush and our international competitors have issued the challenge. It is now up to us to respond.

Thank you for this time this morning and we are very happy to answer any questions that you and other senators may have.

Senator GORE. Very good. Thank you for your statement. Last year the Congress enacted amendments to the Commercial Space Launch Act to make the domestic ELV industry more competitive with foreign launch companies, and at the same time to equitably spread the risk between the private sector and the Federal Government. Have these amendments been successfully implemented by your office?

Mrs. LEE-MILLER. Yes, they have. Insurance standards were set for the successful SSI launch, and we are also working with

McDonnell-Douglas to establish the insurance rates for them as well. And we are working with industry and continuously soliciting their input into the implementation of the amendments. And so far, we are very pleased with the progress that has occurred.

Senator GORE. Well, now, at what point does the government indemnification kick in? Before the launch or after the launch? And for what duration does it extend after the launch?

Mrs. LEE-MILLER. Well, the insurance includes the preparation phase before the launch. And so, essentially, when the entry onto the facility begins in preparation for the actual launch, the coverage begins in terms of how long the insurance lasts after the launch, this varies from launch to launch.

In the instance of SSI the insurance coverage was for the term of the launch which was about 17 minutes. In the instance of McDonnell-Douglas the insurance coverage will go on for 30 days after, and so there are a number of factors, and it really has to be developed on a case-by-case basis.

Senator GORE. Well, has enactment of this amendment made the industry more competitive with foreign launch services, can you tell?

Mrs. LEE-MILLER. We certainly believe so, having the Federal Government enter the picture and share the risk has certainly provided an environment for the companies to feel more secure. And having the government indemnify beyond a certain ceiling of insurance coverage puts the U.S. business in a more secure position. And, of course, this contributes to our competitive position worldwide.

Senator GORE. Are additional steps required to ensure the competitive posture of the U.S. industry?

Mrs. LEE-MILLER. We absolutely think so, and we think that the U.S. government should aggressively look at several areas of concern that we have uncovered. One—and this was indicated earlier in Mr. Rose's testimony—we must look seriously at improving the infrastructure of the range facilities and the launch pads and just the general infrastructure services that are provided to the industry.

We also must look at what I kind of term as new thinking. In order for us to establish policies that are going to aid our industry, new thinking really is in order in the area of procurement.

If the government continues to pursue what was stated very clearly in U.S. space policy: that government should, wherever possible and wherever is feasible procure commercial launch services, the government is acting in the role of customer.

In some instances within government agencies this is going to require a new approach, a new attitude, looking at launch services differently, looking at procurements differently, and we urge that.

Third, we would like to see the government look at targeting research and development and particularly in component technologies. We feel that this is a role that the government can play as well.

And, fourthly, we are continuing to work within DOT and with other Federal agencies to continue the dialogue on international principles and enforcement mechanisms to govern the international marketplace.

Senator **Gore**. What was the first on your list?

Mrs. **Lee-Miller**. Improved infrastructure, working with the infrastructure within the launch industry to improve capacity.

Senator **Gore**. All right. Let me just express my own concern here. In 1981 the United States controlled 100 percent of the western world commercial launch business. With the advent of Ariane that percentage was reduced to 50 percent. As a result of last year's agreement with the People's Republic of China, some argue that that percentage has been further eroded to 35 percent of the market.

I think the picture is—the picture that emerges from these and many other trends is not a very good one. The ELV industry here faces a basically stagnant market and growing competition. The prospects do not look good.

We need an arrangement between the U.S. government and the industry to stay in the business. So, when you talk about the need for new thinking, I agree with that. I am not sure that the list you provided can be viewed as all-inclusive. You are not pretending that it is, and you include reference to a continuing dialogue, and I suppose that points us toward consideration of a government industry initiative that is broader in scope and deeper in commitment.

I am wondering whether or not you think a specific goal should be established, maybe 50 percent of the commercial launch market by 1992? Do you think that is a good idea and would you recommend any specific steps other than that?

Mrs. **Lee-Miller**. Well, Senator, you have before you representatives of the Office of Commercial Space Transportation who are very ambitious on behalf of the commercial launch industry.

We recognize that there is great concern here up on the hill about the status of the launch industry, but we are optimistic based upon what we see in our office, we know that U.S. launch companies now have commitments to conduct 10 commercial orbital launches in fiscal year 1990. That is 2.5 percent over what we are looking at in 1989.

So, from our perspective this is progress. We know that our launch manifest shows U.S. companies with an order book of 20 orbital launches over the next five years. Twelve of them will be from foreign or international customers. We think that this is positive. We are expecting as many as 20 launches in 1990. So, from our perspective, we see growth, we see the companies working very hard to be competitive, we see the companies being very aggressive.

Your question about goals, absolutely. I think the United States as a nation should establish a goal, not to achieve 50 percent of the market share, but to achieve more. Why should the U.S. industry not set a goal to absolutely be the leading industry in the commercial——

Senator **Gore**. What goal would you set?

Mrs. **Lee-Miller**. In terms of numbers? Higher than anyone else in the market. Whatever they are at, we want more.

Senator **Gore**. Well, Fifty percent would be higher than anyone else.

Mrs. **Lee-Miller**. Fifty percent would be higher, and I think that is an admirable goal, as you have indicated. But if we find the competition accomplishing 50 in the future, then we should not be satisfied with 50 but keep moving forward.

This country responds well to goals. Certainly when we decided to put a man on the Moon, we did. And so I favor the government being ambitious and setting its sights and then let us get the policy to line up with achieving that.

Senator GORE. Let me ask a few questions on rules of the road. Does the U.S. government intend to maintain its ban on the launch of U.S. satellites on the Soviet expendable launch vehicles?

Mrs. LEE-MILLER. Yes.

Senator GORE. Will your office play any role in the recent protest by Space Commerce Corporation of the NASA medium ELV launch because foreign launch services were prohibited from competing in this case, in this particular case the Soviet Proton launch vehicle?

Mrs. LEE-MILLER. Our role will be to support the decision of NASA. It is a NASA procurement that is in question, and we will support NASA's decision not to include the Soviets as competitors for that.

Senator GORE. Is it the intent of the United States to negotiate a launch services agreement with ESA, the European Space Agency?

Mrs. LEE-MILLER. There are some informal discussions going on now with ESA. The U.S. government has not decided yet whether to enter into formal discussion at this point, but we are certainly in constant contact with the European space agency.

Senator GORE. Why would we pursue a series of bilateral agreements, first with the People's Republic and then with ESA, the People's Republic of China and then with ESA instead of a multilateral agreement with the launch nations of the world?

Mrs. LEE-MILLER. I am going to refer that question to Gerald Musarra. He chairs our international trade committee within our office.

Mr. MUSARRA. Well, first of all, as Ms. Miller indicated, there has been no decision as yet whether to pursue negotiations with the Europeans and actually to enter into an agreement with them.

The agreement with the Chinese was certainly much narrower in scope than anything that might be contemplated with the Europeans and in some ways, really, it is kind of an apples and oranges-type comparison.

The agreement with the Chinese really is all about quotas and the distribution of commitments and so on. Any agreement with the Europeans would be more about market practices and in particular the kinds of support that is provided to launch providers and once again, specifically what are called the indirect supports and inducements.

That said the agreement with the Chinese does specifically contemplate that some sort of multilateral arrangement would indeed be a worthy goal in this area. And so, it certainly has not been precluded.

Senator GORE. What role does your office play in overseeing that agreement with the People's Republic of China and when is the first formal review of the implementation plan scheduled?

Mrs. LEE-MILLER. Our office is represented on the interagency committee which is chaired by the U.S. Trade Representative's office. The commercial space subgroup of that interagency committee has specific responsibility for monitoring the People's Republic of China Agreement. In addition to that, we serve as chair. Mr. Musarra here is chair of the information working group which is a committee designed to investigate exactly what is occurring within the industry and to solicit information from our companies about what they are hearing that the Chinese are doing.

We also have an internal task force within our office that is continuing to monitor this very seriously. We hear from industry on a continuous basis about their concerns about this agreement, and let me say at the outset that our office entered into the process of negotiating the Chinese agreement with some trepidation.

It was this office's concern that it would be difficult to frame an agreement that could protect the industry in a manner that protected the market from our point of view. However, now that we are in it and it was our choice to develop and it was signed in January, we are now committed to reviewing it to see if any violations occur and if we do perceive based upon hard evidence that violations are occurring, our office will be the first to cry uncle so to speak and to demand that there be some redress on behalf of the commercial launch industry.

Senator GORE. Why are precise definitions of key terms not included in this agreement and implementation plan? For example, the phrase "on a par with those prices, terms and conditions prevailing in the international market"?

Mrs. LEE-MILLER. It was the intent of the committee during the negotiations process, and I was not there, but Gerald was. But it was the intent of the committee to leave some flexibility, to make those determinations in light of real market conditions and real-world fact situations.

However, Senator, it is my conclusion upon listening to the debate as it has been reported to me from those discussions, that there was some inability of the Federal agencies perhaps to agree on some of these terms. And while there was a desire to maintain flexibility, unfortunately in government sometimes, government agencies just do not always see things the same way.

Senator GORE. You are kidding.

You are new at this job, are you not?

Mrs. LEE-MILLER. New to this job, not new to government. But, having sat through many, many meetings, and we know how it goes. Everyone has got their own agenda they are bringing to the table, and frankly that resulted in a lack of clarity.

Senator GORE. What mechanisms exist to enforce the agreement?

Mrs. LEE-MILLER. The only muscle that I have been able to determine in the enforcement of this agreement is really the State Department's right to grant export licenses or withhold them, and that is where the enforcement—that is really where it is going to be.

If we feel the agreements are violated, then future requests for launches, those licenses can be withheld.

Senator GORE. If there is a lack of clarity on the part of the U.S. government because we could not quite get our act together, how can the PRC use this lack of clarity?

Mrs. **Lee-Miller**. Well, Senator, vagueness certainly allows for lots of activity. In terms of how they may use it, I think I will bounce that question over here to Gerald to respond to you.

Mr. **Musarra**. Well, I think that frankly is the answer, that the vagueness is something that on the one hand may afford us some flexibility. It affords them some as well.

And I think that to the extent that——

Senator **Gore**. Did you find that the various Chinese negotiators arguing with each other and in a state of confusion about what their overall goals were?

Mr. **Musarra**. None was evident to me.

Senator **Gore**. That was just on our side?

Mr. **Musarra**. That is right. Of course, I was not present.

Senator **Gore**. I am not accusing you.

Mr. **Musarra**. No, but they seemed to be very clear in terms of what they wanted out of this process.

Senator **Gore**. That is not unusual for us to approach international negotiations that way. Should U.S. manufacturers of satellites be free to package their equipment with foreign ELV sources if that gives them the cheapest package?

Mrs. **Lee-Miller**. Well, Senator, certainly we believe in free marketplace. And I am going to ask, Norm, would you like to respond to that question?

Mr. **Bowles**. The problem that is presented by that dilemma is that the satellite industry is linked. The future of the satellite industry in the United States appears to be linked to the state of or to the launch vehicle in the sense that if an American satellite company is not permitted to launch on a foreign operator and that foreign operator has among the lowest launch packages, then if another foreign satellite manufacturer teams with that foreign operator, then they are actually able to undersell Americans. That was what the issue was with respect to the Long March. Hughes had gone out and competed, and the PRC was offering the lowest vehicle-price combination. Other foreign satellite manufacturers were willing to team with the PRC, and so Hughes was not going to be able to meet that package deal. And so, that is what the dilemma is.

If we do not permit American companies to fly foreign—not only forgetting the PRC—but Ariane or whatever, we actually risk losing our satellite industry. And so it appears that the real heart of the issue is that we have to have a very highly competitive U.S. launch industry, not try to prevent American companies from being able to launch on foreign operators.

Senator **Gore**. Well, what is the answer to the question, though? I mean, if I heard you correctly, your answer is no. U.S. manufacturers of satellites should not be free to package their equipment with foreign ELV sources if that gives them the cheapest package.

Mr. **Bowles**. No, they should be permitted to launch aboard whatever foreign system provided in order to sell their services abroad. That was the director's—I agree with the director on that.

Senator **Gore**. Are you sure? You all want to consult among yourselves on the answer to this question?

Mr. **Musarra**. I think as a general matter it depends upon who they are packaging with and what the circumstances of the arrangement are. Clearly when Hughes proposed to do something very much like that with the Chinese launch vehicle, we opposed it.

We do not think it was in the interests of the commercial launch industry or in the long-term interests of the satellite industry.

We have, of course, "we" being the government, has approved proposals to launch U.S. satellites on the European vehicle, the Ariane vehicle. I think that is really does depend, as I said, on who the players are and what the arrangements are.

Senator Gore. The fact is, the ELV industry is not really a free market, is it?

Mrs. Lee-Miller. Well, at this stage, I guess, we are looking at short term and long term. In the long term we certainly want the ELV market to be a free market.

Senator Gore. Well, it does not matter. I mean, it may not matter much what we want. If foreign governments are intent on subsidizing launches to attract a larger share of the launches each year, then it will not matter whether we wanted to be a free market or not, will it?

Mrs. Lee-Miller. I think you are absolutely right and, Senator, let me suggest that the line of questioning—and you are seeing us kind of huddled here to try to respond to you in an accurate manner—the U.S. Government needs to establish better international principles in this whole game. We do not have clear answers. We do have a case-by-case—each case that comes up, we have to kind of huddle and come up with a response.

I think that there needs to be better overall planning and there needs to be more discussion and more interaction with you and with others concerned about this matter, and so I hesitate to give you any pat answers on a subject like this, frankly.

Senator Gore. Okay. We will pursue it on other occasions. I really appreciate your testimony and your appearance here today, and I wish you well, Mrs. Lee-Miller, in your new position. And I thank you and your associates and our other witnesses this morning.

We will have additional questions in writing. If you will respond for the record, we would certainly appreciate it.

And with that, this hearing will stand adjourned.

[Whereupon, at 11:35 a.m., the committee adjourned, subject to the call of the Chair.]

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORE AND THE ANSWERS OF MRS. LEE-MILLER

HEALTH OF DOMESTIC ELV INDUSTRY

QUESTION:

Your Office is responsible for promoting the domestic ELV industry. To improve your understanding of this industry, a Commercial Space Transportation Advisory Committee (COMSTAC) has been established.

> Would you please tell the Subcommittee what the principal items are on the COMSTAC agenda? Has COMSTAC addressed the issue of trying to formulate a model commercial launch services agreement or the need for tax incentives for domestic ELVs?
>
> What is the overall health of the domestic ELV industry, and how many U.S. launch firms are currently in the business? Does the availability of launch services exceed the demand for such services? What is the projected market for domestic ELV?

ANSWER:

Recent COMSTAC agendas have included component technology, access of foreign nationals to U.S. ranges, radio frequencies for launch telemetry, insurance, international trade, government procurement, scheduling, and spaceports.

A COMSTAC Procurement Working Group has been addressing the issue of government procurement and is considering a possible model commercial launch services agreement. Also, COMSTAC has considered possible tax incentives for commercial space transportation.

Our diagnosis of the overall health of the domestic ELV industry is good; our prognosis of its future health is excellent. There are now four established U.S. firms which have supplied launch vehicles and services to the U.S. government over the last 25 years; these firms are General Dynamics, LTV, Martin Marietta, and McDonnell Douglas. In addition a number of new-start firms are seeking launch contracts; these firms include American Rocket Company, Conatec, E'Prime Aerospace Corporation, Orbital Sciences Corporation, and Space Services, Inc.

Until the backlog of payloads resulting from the Challenger accident is worked off in the 1990s, the demand for geosynchronous launch services will continue to exceed the supply.

SPACE TECHNOLOGY INVESTMENT

QUESTION:

A recent Space Business News article indicated that the Commercial Space Transportation Advisory Board said that "unless the U.S. government is willing to target its space transportation technology investments to benefit the fledgling commercial launch industry, there may be no industry a decade from now."

Mrs. Lee-Miller, does that accurately represent the view of the domestic ELV industry?

What steps is DOT taking to address this matter, and have you discussed this issue with NASA since they were instructed in last year's Commercial Space Launch Act Amendments (P.L. 100-657) to design, in consultation with the space launch and satellite industry, a program for the support of research into launch systems component technologies for the purpose of developing higher performance and low cost launch vehicles?

ANSWER:

The consensus of the domestic ELV industry is that the U.S. Government does have an important role to play in advancing space transportation technology. At the same time the industry realizes that each company will also be investing in improvements in vehicle-specific technology.

The Office of Commercial Space Transportation has discussed the component technology issue with NASA and with the Commercial Space Transportation Advisory Committee. We intend to pursue these discussions further.

Commercial Launch Facilities

There has been much discussion about the development of commercial space launch facilities in Florida, Hawaii, Texas and Virginia.

> Could you give the Subcommittee an update on these activities, and what role, if any, your Office plays in the development of commercial launch facilities?
>
> Does the domestic ELV industry require a "commercial launch facility," and is the industry encountering any problems with launching on existing federal launch facilities pursuant to existing Range Use Agreements?

Under the Commercial Launch Space Act, the Department of Transportation is authorized to license commercial launch sites. There have been no applications for commercial site operator's licenses. However, the States of Florida and Hawaii have both announced commercial spaceport proposals. Florida has created a spaceport authority and authorized $210 million bonding. The proposal for Hawaii has reached a point where DOT and Hawaii have decided to initiate development of a joint federal/State Environmental Impact Statement.

The number of anticipated launches exceeds the existing capacity of the government ranges as indicated in the recently released report entitled, Scheduling Commercial Launch Operations at National Ranges. This need for additional capacity might be met by commercial spaceports.

Yes, the domestic ELV industry is encountering problems, even though OCST believes that government range operators are attempting to provide services to commercial launch companies in the best manner possible. Specific issues raised in the previously mentioned report that support this conclusion include:

- Limited capacity of the launch facilities.
- Limited availability of support assets.
- Policies detracting from a commercially reasonable operating environment. These policies have the effect of increasing costs and making U.S. launch companies less competitive in the international market.

FY 1990 DOT Office of Commercial Space Transportation Budget Request

In FY 1990, the Office of Commercial Space Transportation budget request is for $4.4 million.

> In light of the expected increase in domestic ELV launches in the next two years, does this budget request provide your office with the funds necessary to license and regulate this industry and to protect the public health and safety?
>
> What steps are you taking to augment the technical capabilities of your office to ensure effective execution of your Office's roles and responsibilities?

The year 1990 has been marked by the strong success of the major U.S. launch companies in securing launch business and the emergence of new companies with new launch concepts such as the air-launched Pegasus. The result has been an increase in licensing and inspection actions. Although we believe the proposed budget request will allow us to perform all necessary regulatory actions and protect public health and safety, the budget will be very tight. We might experience problems if:

(1) the full budget request is not funded, or

(2) industry growth accelerates.

OCST continued to add highly qualified technical staff during FY-89 and plans additional recruitment of aerospace engineers during FY-90. In addition, three major contractors are providing technical support to OCST.

We estimate that about 15 communications satellites per year will be launched to geosynchronous orbit between 1989 and 1994, excluding the Soviet and Chinese domestic markets. In addition, we anticipate launches of payloads for remote sensing, materials processing, navigation, and other purposes. However, there is significantly more uncertainty about the nature and scope of the demand for such launches.

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF HON. THAD COCHRAN, U.S. SENATOR FROM MISSISSIPPI

Mr. Chairman, I appreciate your holding this hearing to review the report by the Aerospace Safety Advisory Panel on NASA's Advanced Solid Rocket Motor (ASRM) program, and providing me an opportunity to present my views on the need for this program.

I am pleased that NASA has designated two sites in the State of Mississippi for production and testing of the Advanced Solid Rocket Motors. This program will provide more than 1,700 jobs in a region where unemployement is higher and income levels are lower than most other regions of the United States.

Despite the benefits this program would bring to my State, I recognize that the development of the ASRM is essential, in a broader view, to the fulfillment of our national goal of U.S. leadership in space.

Americans have watched with enthusiasm the Shuttle's return to space flight, a magnificent accomplishment following the Challenger tragedy in 1986. Since last September, the Space Shuttle has completed three successful flights to place in orbit satellites that will support future missions, and, most recently, to renew planetary exploration with the deployment of the Magellan probe to Venus.

The NASA team directed by Admiral Richard Truly that led America back into space has determined that the ASRM is critical for making improvements which will allow our space program to move forward. Last year, Congress agreed by endorsing the ASRM and appropriating funds for its implementation.

I will defer to Admiral Truly and the other experts at NASA to respond to the questions raised by the Advisory Panel concerning the technical need for the ASRM. NASA has already determined that the ASRM design will enhance reliability by eliminating hundreds of failure points found in the Redesigned Solid Rocket Motor. It has determined that the ASRM design will provide significant safety improvements, and will provide the Shuttle with the capability to lift heavier payloads into orbit for construction of the space station.

If America is going to continue the progress we have made toward rebuilding our space program, it is vital that Congress provide NASA with the necessary resources to improve reliability, safety, and performance of space flight systems.

I urge the Subcommittee to continue its support of NASA's commitment to the ASRM program.

STATEMENT OF JERRY GREY, DIRECTOR, SCIENCE AND TECHNOLOGY POLICY AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, WASHINGTON, DC

INTRODUCTION

The American Institute of Aeronautics and Astronautics (AIAA) is a nonprofit professional society dedicated to advancing the art, science, and technology of aeronautics and astronautics and to promoting the professionalism of those engaged in these pursuits. We have a membership of over 40,000 drawn from all levels of American industry, academia, private research organizations, and government as well as from numerous nations abroad.

For many years the Institute has emphasized the importance of a strong civil space program for advancing science and technology, improving the human condition, and maintaining this nation's international prestige, national security, and economic competitiveness. Investments in the civil space program promote economic growth and therefore increase the federal revenues needed to support essential government services.

The U.S. today is faced with ever-increasing competition from foreign governmental, commercial, and pseudo-commercial space ventures which are heavily subsidized by their governments. The next decade will determine how well the U.S. is able to meet that competition. Despite serious and valid concerns about the federal deficit, spending cuts aimed at reducing near-term budget pressures can have a devastating impact on our ability to achieve long-term goals designed to maintain our economic, political, and scientific leadership in the modern world.

The advent of a new administration offers us a unique opportunity to begin the new decade by reshaping the American space program to meet both the technological and the political challenges of the 21st century, not the least of which is the high-profile Soviet space program. In 1961, the United States space program faced a similar challenge from the Soviet Union. On May 25 of that year, President Kennedy delivered this message to the American people:

> "Recognizing the head start obtained by the Soviets with their large rocket engines, which gives them many months of lead-time, and recognizing the likelihood that they will exploit this lead for some time to come in still more impressive successes, we nevertheless are required to make new efforts on our own. For while we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will make us last."

America's response to President Kennedy's challenge brought us the outstanding success of Apollo and unquestioned global leadership. A comparable commitment now to national long-term goals could make 1990 the first watershed year for America's civil space program.

The AIAA has formulated three such goals for a national space policy:

(1) Expand our current efforts to understand the Earth, the near-Earth environment, the Sun, the Solar System, and the distant universe.

(2) Extend human presence beyond a permanently occupied Earth-orbiting space station to the Moon and Mars.

(3) Enhance the competitiveness of U.S. industry in launch vehicles and space applications such as satellite communications, navigation, and Earth observations as well as in space-related services, information, and eventually products.

This final goal can be restated more explicitly: create a profitable space industry, which in turn will stimulate private sector investments, maintain and improve U.S. global economic competitiveness, generate economic benefits for the U.S. populace, and enhance the quality of life on Earth.

The Institute has also noted that achievement of these goals will require comprehensive research programs, broadly based technology advancement and demonstration efforts, long-term commitments to infrastructure development, construction, and operations, and assured access to space. Substantial investments are also required to revitalize and improve the quality of U.S. education in science and engineering at all levels.

These goals and the prerequisite activities needed to achieve them are not costly relative to other federal investments in the nation's future. However, we recognize the powerful deficit-reduction pressures imposed on the formulation of annual budgets, and we acknowledge the unfortunate fact that such pressures may compromise vigorous pursuit of the above-stated goals. We urge that when considering such compromises you keep in mind these overriding guidelines:

(1) The space technology base is the foundation on which all future space activities and capabilities depend. Support for that base must not be allowed to decay, even though much of its payoff will come in the future.

(2) Completion of current programs, both in science and in infrastructure development, should generally take precedence over the introduction of new programs. Once a program is approved and initiated, it should be completed on schedule and on budget.

Program delays and stretchouts always increase costs, and often reduce capability, motivation, and accomplishment; such delays must be avoided.

(3) Cutbacks in advanced research, technology, and development spending must be avoided if they will result in substantially higher development or operations costs later. While lower front-end costs may seem attractive in an austere budget environment, planning objectives must focus on minimizing overall life-cycle costs.

We believe the FY 1990 budget proposed by the administration is for the most part consistent with pursuit of the long-term goals espoused by the AIAA and with the three above-stated guidelines. Our views on the detailed programs within that budget are as follows:

SPACE TRANSPORTATION

Safe, reliable, and timely access to space is essential for a successful U.S. space program. We applaud the return of the Shuttle to flight status, but urge the expansion of efforts to establish a mixed fleet of expendable and reusable launch vehicles, both government and commercial, that can both meet growing U.S. launch needs and compete with ever more capable and numerous foreign launch operators.

With the Shuttle's return to flight status, the proposed increased funding of the Orbiter's extended-duration on-orbit capability makes good sense; even more extensive improvements may be required in the future if the Shuttle is to continue to serve us over the next few decades. In consonance with the funding guidelines noted earlier, we strongly support the proposed significant increase in space research and technology activity aimed at improving our ability to transport payloads, both in orbit and from the Earth's surface into space. Current R & D in this area should be focused on improving the reliability and lowering launch and overall life-cycle costs for transportation systems. In addition to NASA research and technology programs, the current Advanced Launch System (ALS) development effort by the DOD and NASA will avoid duplication of activities and ensure the most efficient use of government resources.

However, the requirements for space-station deployment beginning in the mid-1990s will impose a transportation demand on the Shuttle which has been identified by the National Research Council as its foremost concern in the entire space-station program. One alternative is the development of a Shuttle-derived unmanned cargo vehicle, Shuttle-C, able to loft as much as 150,000 lbs. per flight into low-Earth orbit. This interim capability, although clearly not a substitute for the ALS because of its high recurring cost and limited operational flexibility, could help to alleviate the heavy Shuttle manifest in the mid to late 1990's, thereby reducing the chances of a Shuttle mission failure during space-station deployment. Although such a vehicle would require some additional budget commitment for development of the unmanned payload carrier to replace the orbiter, there is a possibility that some of that investment would be made by the private sector if NASA were able to make a commitment to purchase the necessary number of Shuttle-C launches. If for no other reason, the relatively high probability of a Shuttle mission failure sometime during the next decade at projected launch rates warrants serious consideration of the Shuttle-C alternative.

With or without a Shuttle-C commitment, however, upgrading of the Shuttle's reliability through the use of advanced boosters is needed. NASA has recognized this need by initiating an Advanced Solid Rocket Motor (ASRM) development and also by conducting a Liquid Rocket Booster study. One of these alternatives should be implemented in time for space station deployment in the mid-1990s if possible. Development efforts in this area should focus on providing a smooth transition to next-generation launchers such as ALS and advanced Shuttle designs.

It is also necessary to look beyond the Shuttle and even ALS technologies toward future space transportation systems that are more cost-effective and reliable. We must begin developing the technologies now that will enable such a system and designing the incentives that will drive us toward it. The AIAA applauds this Subcommittee's action last year in supporting the joint NASA/DOD effort on R & D for the hypersonic National Aerospace Plane.

The government can also lend its support to the budding U.S. commercial launch industry and thereby ensure the availability of a robust mixed-fleet capability by emphasizing the importance of purchasing required launch services wherever possible and by not competing with commercial firms for nongovernment payloads. The AIAA applauds the recent Commercial Space Launch Act Amendments, which go a long way toward minimizing insurance barriers to commercial launch activities. Future legislation could address additional concerns such as the availability of affordable first-

and second-party insurance. These measures, along with continued effective regulatory reform, will support U.S. industry's ability to develop the world's lowest-cost, most capable, and most reliable launch service system.

Other actions which will facilitate the development of a broad "mixed fleet" transportation capability include ensuring that the minimum number of operationally available Shuttle orbiters is maintained at four, investing in advanced technology areas critical to the development of next-generation vehicles, and expanding the use of cooperative industry-government instruments such as Joint Endeavor Agreements (JEAS) and Space System Development Agreements (SSDAs) to encourage the upgrading of commercial expendable launch vehicles.

Efficient in-orbit transportation is also essential to low-cost space operations. The AIAA therefore supports the requested budget increase for the orbital maneuvering vehicle (OMV), which can both extend the Shuttle's capabilities and play an important role in the deployment and operation of Space Station Freedom. We also see the need for intensive technology development leading to a new, fully reusable high-energy upper stage for future geocentric operations, lunar and Mars exploration, and missions to the outer planets.

SPACE STATION FREEDOM

A space station is an essential feature of almost every long-term space plan proposed in the past two decades. Because the development and deployment of Space Station Freedom will require a significant fraction of NASA funding during the next decade, it will be a prime target for spending cuts in the constrained budget environment of the coming years. However, it is imperative that this program receive support at the level requested in both the current NASA budget proposal and the multiyear authorization approved by this Subcommittee last year. The costs of building, deploying, and operating Space Station Freedom will be repaid many times over through the economic, social, and political benefits it will provide to this country.

Space Station Freedom will restore U.S. leadership in manned space and provide a source of international prestige and national pride in which all Americans can share. It will also continue and strengthen the U.S. tradition of international cooperation in space. We have already signed agreements with our allies in Japan, Europe, and Canada, receiving from them commitments both to develop Station elements and to provide substantial financial support.

The unique space environment of Freedom's laboratories will make it possible to conduct space science research and technology development that cannot be performed on Earth, in astronomy, astrophysics, space applications, space processing, and biomedical and life sciences research. Station facilities will enable us to conduct zero-g experiments of unprecedented length and complexity, providing valuable data and experience for extended duration human space exploration. It will serve as an observatory for critical biospheric Earth processes and augment the Earth observation capabilities developed through Mission to Planet Earth activities. Freedom will provide critical support to the U.S. manned space program by facilitating advanced instrumentation research, serving as a platform for the assembly and launching of deep-space transport vehicles, and providing a base from which to conduct in-space servicing activities. The Space Station is an integral element in any future exploration strategy, whether the final destination is the Moon or Mars.

Commercial space development in the U.S., vital to future economic competitiveness and trade (as has been recognized by all the other spacefaring nations), will be much strengthened by the access of U.S. industry to a permanent in-space experimental facility. Space Station Freedom will facilitate research on new processes and products, and on technologies such as future-generation supercomputers, space sensors, pharmaceutical products, and instrumentation.

Because the Station will be in operation for decades, operations assessments must be funded and infused into the program at an early stage. The recommendations of NASA's Space Station Operations Task Force (SSOTF) are aimed at reducing the costs of space station operations and encouraging industrial participation; they should be implemented expeditiously.

The AIAA concurs with the National Research Council's finding that the current space station design is the appropriate one, and we believe, further, that the funding requested is indeed the minimum required to fulfill Freedom's mission requirements. In that context, President Kennedy's historic 1961 announcement of the Apollo program is again especially pertinent:

> "If we are to go only half way, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all...But I think every citizen of this country as

> well as the Members of the Congress should consider the matter carefully in making their judgment, to which we have given attention over many weeks and months because it is a heavy burden, and there is no sense in agreeing or desiring that the United States take an affirmative position in outer space, unless we are prepared to do the work and bear the burdens to make it successful. If we are not, we should decide today and this year. "

This philosophy is exactly in accord with our above-stated guidelines. The AIAA therefore enthusiastically supports this Subcommittee's unprecedented action last year in authorizing multi-year budgeting for the space station, which allows the cost savings that accrue from proper management of long-term commitments and planning. The current practice of partial or phased funding within a budget year is especially devastating to the orderly management and budget control of any development program that extends over almost a decade. Indeed, rather than cutting funds and slowing down the program, now that it has been approved Congress should direct NASA to get Space Station Freedom on line at the earliest practical date. It is indecision we cannot afford.

HUMAN EXPLORATION

As noted earlier, we consider exploration to be one of the most important national goals of the U.S. civil space program. However, we believe that extension of human presence beyond low Earth orbit should proceed methodically rather than with an Apollo-type "leap." We commend the efforts of NASA's Office of Exploration in formulating "exploration strategies" for future missions to the Moon, Phobos, and Mars. Regardless of the final destination selected, however, extensive planning, precursor missions, and advanced development must be part of the mission planning process. Priorities must be established at the outset and pursued in an orderly manner throughout the entire process.

However, long-term exploration research and planning efforts must receive proper funding if we intend to be one of the leaders in future space endeavors. The FY 90 budget request for NASA's Office of Exploration (Code Z) is inadequate to provide the strong base required for any large-scale exploration undertaking, although the office's performance to date with the limited funds available has been outstanding.

In addition to a strong planning base, human exploration missions will require a more complete understanding of how living systems react to the stresses of space flight. We commend NASA for proposing an FY 90 budget adequate to sustain a forward-looking, balanced program in the life sciences, especially the focus on the 1.8-m centrifuge and long-duration crew operations. These and other space-station programs, along with elements of the Pathfinder initiative, are essential to the planning for human exploration of the Moon and Mars. The stretchouts necessitated by last year's Pathfinder program budget cuts should be recovered by increased funding this year in these key areas. We also support the continuation of the joint programs with the Soviet Union on analyzing long-duration space flight and sharing data on space biology and medicine. However, we would like to emphasize the importance of maintaining a balance between scientific and technology efforts; the Life Sciences program must be supported by in-space research and experimentation.

SPACE SCIENCE

The U. S. space science program is a national resource. It requires the aggressive pursuit of worthy goals and a strong commitment to their attainment, to draw talented new people into the field and keep them there.

Planning for space science is the most thorough and comprehensive of all NASA activities. The AIAA strongly supports the long-term program delineated in the recent Space Science Board's six-volume plan, and urges the use of multiyear commitments for these programs to ensure the stability necessary for projects measured in decades rather than years. In that context, we deplore the proposed cancellation of the Gravity Probe B program.

We commend NASA for adhering closely to the Office of Space Science and Applications Strategic Plan, key near-term elements such as the Great Observatories Program (Hubble Space Telescope, Gamma-Ray Observatory (GRO), Advanced X-Ray Astrophysical Facility (AXAF), and Space Infrared Telescope Facility), the planetary exploration program, and the Earth Observation System. We support NASA's aggressive plans in progress for close observation of several planets, beginning with Magellan (Venus) and Galileo (the Jovian system) and then the Mars Observer.

We urge your support for a new start recommended by NASA's Space Science Board: the Comet Rendezvous Asteroid Flyby (CRAF)-Cassini mission, which seeks to discover how our solar system formed and, as a consequence, how life began. CRAF-Cassini will allow us to examine the primordial remnants left by the formation of the planets, frozen in time more than four billion years ago in the comets and planets of the outer solar system.

CRAF will rendezvous with the comet Kopff and accompany it during part of its orbit around the Sun. It will send a penetrator/lander into the comet's nucleus, provide the first direct data on a comet's chemical composition, and offer the first close-up look at how a comet's tail of dust is formed. On its way to the comet, CRAF will encounter an asteroid: 449 Hamburga, taking photographs and other scientific measurements.

Cassini will orbit Saturn, providing extensive observations and conducting mapping of its rings, moons, and magnetosphere. It will also send a probe into the dense atmosphere of Titan, which will provide unique data on processes there which are similar to those in the pre-biotic atmosphere of Earth.

CRAF-Cassini will be the first in the Mariner Mark II Spacecraft class. Mariner Mark II will use hardware and designs from previous missions in conjunction with selected new hardware designs to reduce significantly the cost of both missions. NASA has made an admirable effort to save millions of dollars by combining these two missions, which would cost an additional 0.5 billion if pursued separately. Thus CRAF-Cassini should not be separated and considered on an either/or basis. In addition to the cost-savings inherent in the CRAF-Cassini new start, it has the added attraction of being an international project. European commitments to CRAF-Cassini represent savings to NASA of hundreds of millions of dollars in the development of Cassini's Titan probe and in additional science instruments and propulsion modules.

A new start is strongly favored at this time because CRAF-Cassini is a "perishable" opportunity in several respects. First, ESA's financial commitments are substantial, and the agency's selection process is such that they cannot wait another year. Further, the baseline launch windows are in 1995 (CRAF) and 1996 (Cassini). A delay of 1.5 years in the Cassini launch would result in a two-year delay in its arrival at Saturn and the loss of valuable Jupiter fly-by science. A delay for CRAF would be particularly serious because any subsequent development delay could add about 4.5 years to the trip time. Thus, an FY 90 new start provides a much-needed "cushion."

The Explorer and suborbital programs historically have been the proving grounds for innovative ideas in physics and technology and have provided for the application of advanced technologies to current research areas. They have produced most of the currently available information on the ionosphere and magnetosphere, and have served to attract students to space science research and to help them develop expertise in this area. These programs also serve the important function of testing new instruments and technologies prior to their application to larger and more expensive missions. We strongly support this Subcommittee's multiyear procurement philosophy that would extricate funding for these small to medium scale projects from the vagaries of year-to-year funding by authorizing their budgets for periods of at least three years.

The increases proposed for mission operations and data analysis are absolutely necessary to cope with the unprecedented influx of new data and information expected from new spacecraft such as Galileo, Magellan, Ulysses, the Hubble Space Telescope, the Gamma Ray Observatory, the Roentgen Satellite, the Cosmic Background Explorer, and Mars Observer. In addition, funding should be allocated to develop new, advanced methods of handling, accessing, and analyzing this stream of data. Full funding is needed to implement NASA's plans in this area.

MISSION TO PLANET EARTH

The Institute strongly supports the Subcommittee's mandate to NASA to implement the Mission to Planet Earth by 1993; indeed, the recently recognized seriousness of current environmental changes warrants an even earlier system availability. It is not too soon to begin taking the initial steps toward that goal, such as accelerating instrumentation development for the Earth Observation System (EOS). The abovementioned global environmental trends -- the increase in atmospheric carbon dioxide, depletion of the stratospheric ozone layer, and the widespread effects of acid rain and other forms of air pollution -- underscore the urgency of helping to characterize environmental phenomena through space-based observations. The EOS, when complete, will give the best and most comprehensive analytical view ever of Earth as a total system.

SPACE TECHNOLOGY

Technology advancement heads our list of overriding guidelines on funding decisions. Last year we deplored the reductions in FY89 funding for the Civil Space Technology Initiative (CSTI) and the Pathfinder program, particularly the massive cuts in the latter. Although we are pleased to see an acceptable increase in the CSTI request this year, the proposed level for Pathfinder funding continues to be wholly inadequate. Sustained support for CSTI, and especially the long-term commitment required for the Pathfinder program, are fundamental to the future of the U.S. manned space program. We cannot pursue human solar system exploration as a national goal without the advanced technology derived from these programs, both of which will provide major returns in both civil and commercial space sectors.

Although budgetary pressures often result in substantial R&D base cuts, it is precisely during such challenging times that technology advancement can at least keep us in the game and, indeed, may be the most cost-effective way of doing so. We urge that you adamantly support and retain these truly critical programs.

SPACE COMMUNICATIONS

The U.S. still maintains world leadership in supplying commercial communication satellites, but that lead grows more and more precarious as foreign firms, supported by their governments at annual levels measured in hundreds of millions of dollars, develop advanced communications technologies. During the initial successful development of the commercial communications industry, NASA took responsibility for advanced technology and subsequently transferred operations to the private sector. Although the market has now reached maturity (and indeed initial government investments have been returned many times over in industry tax revenues), it is still appropriate for NASA to carry out new and high-risk systems development.

To help sustain U.S. leadership, NASA in recent years has focused its space communications R&D effort on the Advanced Communications Technology Satellite (ACTS) program. While many communications payload capabilities are being developed by the private sector, the critical high-risk technologies represented in ACTS, such as large antenna structures, hopping beams, and advanced on-orbit message processing, have not yet reached the point where their development is commercially viable. NASA must continue to support R&D for future communications technology areas until U. S. commercial interests can assume responsibility for system development, application, and marketing.

COMMERCIAL PROGRAMS

The AIAA applauds the administration's 1988 policy espousing private-sector involvement in space. However, although we endorse NASA's efforts to develop private-sector links via the Centers for Commercial Development of Space and the creation of multi-user, multi-use government hardware, much more can and should be done.

Opportunities for commercial space development exist in at least six areas: satellite communications (currently a mature industry, as discussed earlier), Earth observations, space processing and research applicable to ground-based manufacturing, life sciences, transportation, and ground and orbital services. Although commercialization will be accomplished by the private sector, not the government, the high cost and risk of space ventures and their clear potential for U.S. economic growth call for a strong government commitment to the support of commercial space development. That support consists not only of funds for research, technology advancement, and demonstration (as with the ACTS program cited above, for example), but also of purchasing (rather than providing) goods and services required by the government, not competing with the private sector for provision of goods and services to others, and incentivizing private-sector investment; for example, through cost and risk reduction mechanisms and more flexible regulatory requirements. The government can also support U.S. industry in tapping world markets, and can encourage rather than discourage collaborative mechanisms among industry, government, and academia wherever they would improve U.S. competitiveness with foreign government-supported organizations worldwide.

If NASA takes the lead in developing facilities for industry research leading toward space commercialization, as was done decades ago with wind-tunnel facilities, the initial investment will be returned by the development of new, prosperous industries. At this stage, however, industry cannot be expected to undertake the full investment alone.

The microgravity environment of space can be used to conduct research that could improve ground-processing capabilities, evaluate space processing, and lead eventually to space manufacturing. However, the risks, costs, and time required for a company to return an acceptable profit on investments in space capabilities are all far greater than those of ground-based investment alternatives. Dependable access to low-cost space R&D facilities is currently the most serious obstacle to the pursuit of the research needed to reduce the risks.

To alleviate this problem, the AIAA has advocated expanded use of Spacelab and other Shuttle-borne facilities, and commends NASA's decision to augment the Orbiter's on-orbit duration. In addition, by deploying the Space Station Freedom on schedule, NASA can perform the space R & D that will enable space commercialization, just as NACA wind tunnels supported the commercial aviation industry. The AIAA supports the future use of a Commercially Developed Space Facility (CDSF) to supplement Station Station Freedom activities and to help create a favorable environment for commercial space activities in the latter half of the 1990's. However, CDSF capabilities do not in any way warrant its consideration as a substitute for the Space Station; indeed, near-term CDSF activities should focus on identifying R & D projects for the Space Station which could eventually lead to profitable CDSF experiments and operations.

Additional prospects for near-term commercial space projects and privatization efforts should continue to receive careful consideration. For example, an innovative concept which might prove successful is the recent proposal by the National Academies of Science and Engineering to privatize the operations of several NASA centers or to transfer their management to universities, although such actions may not be appropriate for some time. NASA must carefully plan its course before embarking on efforts to privatize its operations.

In this vein, the AIAA wishes to comment on the provisions in the current proposal for $208 million in private financing for NASA projects. Dr. Fletcher himself has expressed some reservation about whether NASA will be successful in securing these funds, particularly for "higher-risk" items such as the Flight Telerobotic Servicer (FTS) and the Space Station Docking Module. There has been a notable absence of concurrence on this issue by industry, and until this is forthcoming, NASA should be prepared to provide alternative funding options for these projects.

SCIENCE AND ENGINEERING EDUCATION

The decline in U.S. science and engineering education in recent years is a source of considerable concern to the AIAA. Although projected near-term defense budget cutbacks could defer significant problems for the next few years, a strong pool of talented young engineers is a critical element for future American technical and economic competitiveness. Since 1973 the enrollment of foreign nationals in U.S. engineering graduate programs has more than doubled. Today, less than half (about 40%) of the engineering students at the doctorate level in the United States are U.S. citizens. NASA is particularly vulnerable to the diminishing availability of engineers - within two years almost 70% of NASA's 2500 top senior and mid-level managers will become eligible for retirement.

Engineering education suffers not only from limited enrollment but from the poor preparatory training many students receive at the pre-college level. The results of recent studies comparing the various levels of ability in basic science and math skills among students in several countries send a strong message: we are failing to provide adequate education to our students in these areas. The U.S. cannot continue to finish last if we wish to remain internationally competitive technologically, economically, or intellectually. Radical new approaches to pre-college science and math programs, such as that recently proposed by the American Association for the Advancement of Science and other scientific organizations, will certainly contribute to national efforts to get U.S. scientific educational programs back on track.

We believe that the space program can help stimulate renewed interest in science and engineering, by showing students that technical careers can be exciting, interesting, and rewarding. University research activities are strengthened by programs such as CSTI and Pathfinder, which provide graduate students the opportunity to become knowledgeable and to gain hands-on experience in challenging areas of space technology. We support the increased funding proposed for important programs such as the NASA/USRA/University Advanced Design Program, the Space Engineering Research Center Program, and the Space Grant College and Fellowship program. Future efforts to stimulate student interest in space should include students at the pre-college level as well. Space Station Freedom will help to replenish the youthful enthusiasm for science and mathematics that was so evident during the Apollo era, but has sadly diminished in recent years.

CONCLUSION

The AIAA has consistently called for a balanced program of civil space activities, but does not presume to tell the administration or the Congress how to manage individual elements of the civil space program.

We believe, however, that the civil space program today finds itself at a particularly critical juncture in its 30-year history. Recovery from the Challenger failure, the surging growth of overseas capability and competitiveness, the serious economic consequences of the federal budget deficit, the need to replenish our decades-old store of technology, and the recognition of potentially irreversible global environmental changes all call for an unprecedented focus on the role of space in the future of humanity. In addition to the general guidelines we have offered for dealing with the expected pressure to reduce budget deficits, therefore, we believe it appropriate to point out the potentially serious consequences to the nation's space posture of stretchouts or budget cuts in three critical NASA program areas: space technology advancement, space science and applications, and the space station.

The technologies on which our current space activities depend are based largely on NASA programs of the 1960s and 1970s. Many foreign space programs, which began to mature later than those of the U.S., incorporate commensurately more advanced technologies, and are therefore positioned to move more effectively into the 1990s and the 21st century. Investments in technology are relatively easy to postpone, because their payoff is in the future. Such postponements must be resisted, however, because they mortgage our future capabilities, upon which depend our future economic health, our national prestige, and to a considerable degree our national security.

In this context, also, NASA has been subject to much recent criticism for its failure to make commitments to challenging goals in space exploration such as manned missions to Mars or its moons or returning to the Moon. To achieve goals of this scope, however, will require years of dedicated attention to the multitude of technology advancements needed to conduct such imaginative missions. Again, it is all too easy to scrimp on investments in these technologies, despite their relatively low levels, simply because their payoff is so far in the future. But unless we do make those investments and sustain them on a multiyear basis, there is little hope that the spacefarers who eventually do explore the Solar System will be U.S. citizens.

Space science is the base on which our entire civil space program rests. Its funding support does not necessarily have to be huge, but it must be stable and consistent. Most space science programs span one or more decades; the vagaries of year-to-year "crises," whether political, societal, or economic, are anathema to such activities. Nobody can fault the long-term planning for space science; it is perhaps the best to be found anywhere in the U.S. government. That planning should be supported on a long-term, consistent basis that recognizes the need for precursor programs and applicable technology development.

A space station is the single common element (other than transportation) in almost all long-term space plans. Without it, as with a sustained investment in technology advancement, exploration of the Solar System by U.S. astronauts would be extraordinarily difficult if not impossible. The Space Station Freedom's design has been subjected to exhaustive reviews. In one of the more recent of these, the National Research Council concluded that the presently conceived station design cannot be materially improved with current knowledge. Foreign governments have committed nearly $8 billion to its development and deployment. It will provide a permanent human presence in space, along with the infrastructure needed to support future space exploration, Earth observations, orbital servicing, microgravity research and eventually processing, commercial development, life science experiments essential to long-term human activity in space, and development of future space capabilities. Stretchouts and delays can only increase its life-cycle cost and reduce its long-term effectiveness.

Thank you for this opportunity to present our views on the civil space program.

F.A.S.

FEDERATION OF AMERICAN SCIENTISTS
307 Massachusetts Avenue, N.E.
Washington, D.C. 20002 (202) 546-3300

Andrew M. Sessler *Chairman*
*Robert M. Solow *Vice-Chairman*
George A. Silver *Secretary*
Carl Kaysen *Treasurer*
Jeremy J. Stone *President*

Board of Sponsors
(Partial List)
*Philip W. Anderson
*Christian B. Anfinsen
*Kenneth J. Arrow
*David Baltimore
Leona Baumgartner
Paul Beeson
Lipman Bers
*Hans A. Bethe
*Konrad Bloch
*Norman E. Borlaug
Anne Pitts Carter
*Owen Chamberlain
Abram Chayes
Morris Cohen
Mildred Cohn
*Leon N. Cooper
Paul B. Cornely
Carl Djerassi
*Renato Dulbecco
John T. Edsall
Paul R. Ehrlich
*Val L. Fitch
Jerome D. Frank
John Kenneth Galbraith
Richard L. Garwin
*Walter Gilbert
Edward L. Ginzton
*Donald A. Glaser
*Sheldon L. Glashow
Marvin L. Goldberger
*Alfred D. Hershey
*Robert W. Holley
*Jerome Karle
*H. Gobind Khorana
*Arthur Kornberg
*Polykarp Kusch
*Willis E. Lamb, Jr.
*Wassily W. Leontief
*William N. Lipscomb
*S. E. Luria
Roy Menninger
Robert Merton
Neal E. Miller
Philip Morrison
*Daniel Nathans
Franklin A. Neva
*Marshall Nirenberg
Robert N. Noyce
*Severo Ochoa
Charles E. Osgood
*Linus Pauling
*Arno A. Penzias
Gerard Piel
Charles C. Price
Mark Ptashne
*Edward M. Purcell
George Rathjens
*Burton Richter
David Riesman, Jr.
Walter Orr Roberts
Carl Sagan
*J. Robert Schrieffer
*Julian Schwinger
*Glenn T. Seaborg
Stanley K. Sheinbaum
*Herbert A. Simon
Alice Kimball Smith
Cyril S. Smith
*Henry Taube
*Howard M. Temin
*James Tobin
*Charles H. Townes
Frank von Hippel
*George Wald
Myron E. Wegman
Victor F. Weisskopf
Jerome B. Wiesner
Robert R. Wilson
C. S. Wu
Alfred Yankauer
Herbert F. York

*Nobel laureates

Statement of
Steven Aftergood
on
Space Nuclear Power Policy Issues

Submitted to the
Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate

Hearing on NASA FY 90 Budget Authorization
April 4, 1989

My name is Steven Aftergood. I am a member of the Federation of American Scientists (FAS) Working Group on Space Nuclear Power and am currently Scholar in Residence at FAS. I am also the Executive Director of the Committee to Bridge the Gap, a Los Angeles-based public interest research organization concerned with space nuclear power technology and policy. My professional background is in electrical engineering and solid state physics.

The Federation of American Scientists has taken an active interest in the development of space nuclear power technologies. As part of a cooperative effort to address the hazards of space nuclear power, FAS and a group of eminent Soviet scientists recently proposed an international agreement to prohibit nuclear power supplies in Earth orbit, limiting their use to deep space scientific missions. Such an agreement is also the objective of recent legislation introduced in the House of Representatives (H.R. 966).

The following remarks present some of the considerations that we believe ought to be taken into account in shaping a space nuclear power policy that is environmentally sound and that enhances international cooperation rather than undermining it.

National Council Members

*Julius Axelrod
Bruce Blair
Deborah L. Bleviss
Rosemary A. Chalk
Thomas B. Cochran
E. William Colglazier
Alex deVolpi
Hugh E. DeWitt
*Dudley R. Herschbach
William A. Higinbotham
Daniel O. Hirsch
Art Hobson
John Holdren *(ex officio)*
Robert W. Kates
Barbara G. Levi
Francis E. Low
Jessica Tuchman Mathews
Matthew S. Meselson *(ex officio)*
Victor Rabinowitch
Stephen H. Schneider
Andrew M. Sessler
George S. Stanford
Robert A. Weinberg

Facsimile: (202) 543-7555 Telex: 9102509251 FAS DC UQ

Introduction

Together with the Department of Energy and the Strategic Defense Initiative Organization, NASA is engaged in the development of advanced space nuclear power systems. Space nuclear reactors and isotope heat sources can offer high levels of power in a relatively compact form that is enabling for various NASA missions, particularly deep space exploration activities, where the solar flux is insufficient to derive adequate electrical power from solar panels.

However, space nuclear power also poses some serious hazards, due not only to the potential for accidental releases of radioactivity and other environmental disruptions, but also because of the role of nuclear power in provocative military space systems.

In examining the range of current and proposed applications of space nuclear power, it becomes clear that these hazards predominate in missions that are carried out in Earth orbit; they are greatly reduced or nonexistent in deep space missions.

For this reason, the Federation of American Scientists and the Committee of Soviet Scientists Against the Nuclear Threat (led by Academician Roald Sagdeev) have proposed an international agreement to ban the use of nuclear power supplies in Earth orbit.[1] The proposed ban would not restrict the use of nuclear power for missions beyond Earth orbit or on the Moon.

Fortunately, NASA has no absolute requirement for nuclear power in Earth orbit. A review of potential NASA missions reveals that in each case where nuclear power in orbit is an option, solar power systems are also a viable candidate.[2] The same situation, incidentally, pertains with regard to potential Air Force missions. Air Force officials have concluded that space nuclear power is "not an enabling technology" for their needs.[3]

---

[1] Frank von Hippel and Roald Sagdeev, "A Joint Proposal to Ban Nuclear Power in Earth Orbit," Federation of American Scientists, 13 May 1988.

The following discussion briefly addresses several of the problems created by the use of nuclear power that make an international ban on orbiting nuclear power supplies an appropriate and desirable step. These include the potential for an accident; the disruptive effects of orbiting reactors on other spacecraft, including high-value NASA missions; and the disturbing role of nuclear power in provocative military space programs.

Numerous Failures Involving Space Nuclear Power Have Already Occurred

It need not be debated whether accidents involving space nuclear power are possible; many such accidents have already occurred. A striking 15% of all Soviet and U.S. nuclear powered space missions have ended in failure.[4] Several of these released significant amounts of radioactivity into the environment.

---

2. See "NASA's Need for Advanced Nuclear Power Sources," a report to this Subcommittee by the Office of Aeronautics and Space Technology, NASA, January 1989, Table II-1, page II-2. The one exception to this statement is an unlikely network of Air Traffic Control radars, the purpose of which could be far more readily achieved by means of aircraft transponders.

3. Statement of Col. Charles Heimach, U.S. Air Force Space Division, at the SP-100 Project Integration Meeting, July 19, 1988, Long Beach, CA.

4. For further information and source citations, see S. Aftergood, "Towards a Ban on Nuclear Power in Earth Orbit," Space Policy, vol 5, no. 1, February 1989, pp. 25-40.

- o 1964: When the U.S. Transit-5BN-3 navigational satellite failed to achieve orbit on April 21, its SNAP-9A radioisotope power source disintegrated in the atmosphere (as it was designed to do in case of reentry) at an altitude of about 50 km. Release of its 17,000 Curies of plutonium-238 tripled the worldwide inventory of Pu-238, increasing the total plutonium inventory from weapons testing by about 4%.

- o 1965: On April 3, the U.S. Snapshot experimental satellite, bearing the only space reactor launched by the U.S., a 500 Watt SNAP-10A, was launched. The reactor functioned for 43 days before being permanently shut down by a voltage regulator malfunction. While it remains in a long-lived orbit, portions of the satellite have begun to break up.

- o 1968: On May 18, the U.S. Nimbus-B-1 meteorological satellite was aborted following a launch failure, and fell into the Pacific Ocean just off the California coast. Its two SNAP-19A RTGs could not be located for five months but were finally retrieved intact.

- o 1969: A Soviet launch failure occurred on January 25 that may have involved a nuclear powered RORSAT ocean surveillance satellite.

- o 1969: On September 23 and October 22 the U.S.S.R. launched unmanned probes to the Moon. Both achieved Earth orbit, but reentered the atmosphere a few days later. According to various sources, one or both of them carried a polonium-210 heat source, and measurable amounts of radioactivity were detected in the atmosphere following reentry.

- o 1970: A U.S. moon mission, Apollo 13, was aborted in April. Its jettisoned lunar lander fell into the Pacific Ocean The SNAP-27 plutonium power supply has never been recovered, but is assumed to have remained intact. Atmospheric sampling detected no release of radioactivity.

- o 1973: On April 25, another Soviet nuclear-powered RORSAT fell into the Pacific Ocean north of Japan after a launch failure.

- o 1978: In one of the most serious accidents involving space nuclear power, the Soviet Cosmos 954 reentered the atmosphere on January 24, spreading thousands of pieces of radioactive debris over more than 100,000 square kilometers of northwest Canada. A few fragments were sufficiently radioactive (gamma radiation as high as 500 roentgen per hour near contact) to provide lethal doses.

- o 1983: The jettisoned reactor core from the Cosmos 1402 reentered the atmosphere on February 7, where it disintegrated and was dispersed.

- o 1988: Radio contact with Cosmos 1900 was lost in April of 1988, preventing a directed boost of the satellite to a higher disposal orbit. Just days before anticipated reentry, backup systems were finally activated on September 30, and the on-board reactor was boosted to a higher orbit.

The safety hazards of future accidents involving space nuclear power could become increasingly severe considering the increased power level and operational life of the new power supplies now under development.

Some NASA Concepts Are Ruled Out by the "Nuclear Safe Orbit" Standard

One basic safety strategy to minimize the possibility of accidental reentry of an orbiting reactor is to operate it only above a minimum altitude called a "nuclear safe orbit." For an SP-100 reactor this minimum altitude corresponds to about 900 kilometers.

Department of Energy officials[5] had publicly pledged to adhere to this sensible standard:

> We will not start it [i.e. a reactor] up until it achieves what we call a nuclear safe orbit, that is, an orbit that is long-lived enough such that the fission products will decay to a relatively safe level before that orbit decays and the device could possibly reenter and burn up in the atmosphere.

Of the handful of optional NASA applications of nuclear power in Earth orbit, at least two— the growth space station and a materials processing platform-- would involve reactor operation well below a nuclear safe orbit (about 500 kilometers) and would therefore be ruled out by that criterion.

Orbiting Reactors Exacerbate the Orbital Debris Problem

Even those reactors that are deployed or boosted into a nuclear safe orbit present certain hazards because of their potential interaction with orbital debris.

---

[5] Testimony of Stephen Lanes, Director, DOE Office of Defense Energy Projects, in "Space Nuclear Power, Conversion and Energy Storage for the Nineties and Beyond," Committee on Science and Technology, U.S. House of Representatives, October 1985, page 67. According to DOE, this policy has since been "redefined," i.e. rescinded.

The growing problem of orbital debris threatens the near-Earth space environment and the success of future operations in space. The build-up of spent nuclear reactors in orbit could create an additional threat through the proliferation of radioactive debris.

According to Nicholas L. Johnson, the co-author of an authoritative book on the subject, most nuclear powered satellites reside in those parts of near-Earth space that are most densely populated with space debris.[6] A space reactor colliding with such debris "may produce as many as 1,000,000 particles with a diameter of 1 millimeter or more. Some of these particles will be injected into ... regions populated by large, manned spacecraft. Even if these particles do not strike other spacecraft, they will begin to decay at an accelerated rate and reenter the Earth's atmosphere much quicker than previously calculated.... Current [reactor] storage orbit practices ... are insufficient to ensure the protection of continued space activities and of the Earth's biosphere in both the near term and the far term."

Orbiting Reactors Threaten the Operation of Other Satellites

Nuclear reactors used in orbit are largely unshielded in order to minimize their mass and the associated launch costs. As a result, they produce strong emissions of radiation. This radiation has seriously interfered with the operation of other satellites, particularly gamma ray detection systems like that aboard NASA's Solar Maximum Mission, among others.

The gamma radiation and the charged particles (positrons and electrons) emitted from orbiting reactors significantly increase the background noise level that such detection systems must contend with, and can blind them for brief periods several times a day.

---

[6] Nicholas L. Johnson and Darren S. McKnight, Artificial Space Debris, Orbit Books, 1987, pp. 93, 95.

"The situation has become completely unlivable in the last couple of years," according to an astrophysicist working on the Solar Maximum Mission.[7]

The Japanese Ginga satellite has reportedly suffered a "drastic loss of data" due to orbiting reactors and "spends more than 40% of its available observing time transmitting garbage." Instruments launched by the Soviet Union and West Germany have similarly been disrupted.[8]

NASA is now endeavoring to limit the threat from orbiting reactors to its $500 million Gamma-Ray Observatory mission, scheduled for launch in 1990. This might be accomplished by in effect shutting off the satellite at certain intervals before the detection system can be triggered by reactor-generated radiation. This strategy assumes, however, that only one or two low-power reactors will be operating in predictable orbits at any one time.

If the number of orbiting reactors and their power level increase-- as they are likely to do (the SP-100 is 25 times more powerful than current Soviet space reactors)-- the utility of many scientific satellites will be negated.

Nuclear Powered Satellites Increase International Tensions

In evaluating the role of nuclear power in Earth orbit, one must ask whether its applications may not offer some positive benefit that could offset the assorted dangers and defects discussed above. They do not.

---

[7] quoted in William J. Broad, "Radiation from Soviet Nuclear Reactors in Space Hampers U.S. Satellite," New York Times, November 17, 1988.

[8] M. Mitchell Waldrop, "Space Reactors Hinder Gamma-Ray Astronomy," Science, 25 November 1988, page 1119; C. Knox, "Nuclear Satellites Disrupt Research," Science News, November 26, 1988, page 340.

The only current use of nuclear reactors in orbit is for the Soviet Radar Ocean Reconnaissance Satellites (RORSATs) that locate, track and potentially target U.S. naval vessels. These satellites are deemed sufficiently threatening to U.S. national security that they have been cited by the Pentagon as a principal justification for a U.S. anti-satellite weapon program.[9]

Recently, the Director of Naval Intelligence testified that Soviet flight tests of two space reactors in 1987 and 1988 may be part of a Soviet plan to develop space-based laser weapons and could be "a critical step toward deployment of a space-based ASAT by the mid-1990s."[10]

In contrast to such destabilizing applications of orbiting reactors, there is no requirement for nuclear power in orbit for peaceful, civilian applications or for military satellites that might enhance national security (i.e. verification systems). As noted above, solar power is an acceptable alternative for both NASA and Air Force orbital missions. There is also no commercial interest in nuclear powered satellites, due to concerns about launch costs and accident liability.

As for the Strategic Defense Initiative, the SDI Organization has not identified any near-term requirement for space nuclear power; none of the SDI concepts currently under discussion-- SDI Phase I, the Accidental Launch Protection System (ALPS), or Brilliant Pebbles-- include nuclear power.

---

9. See, e.g., U.S. Department of Defense, Soviet Military Power 1985, page 53; and "USAF Official Calls Soviet Satellites Threat to U.S. Carrier Battle Groups," Aviation Week & Space Technology, September 29, 1986, page 20.

10. Statement of Rear Admiral Thomas A. Brooks before the Seapower, Strategic, and Critical Materials Subcommittee of the House Armed Services Committee, 22 February 1989, pp. 24-25. It should be noted that the Soviet reactors in question provide only 10 kilowatts of electricity, far below the level required to power a laser weapon.

Subsequent phases of SDI involving directed energy weapons might entail the use of a large number of high power space reactors. But conversely, a ban on orbiting space nuclear power supplies could create a helpful impediment to the deployment of directed energy weapons in space by all parties.

The current and proposed uses of nuclear power in orbit are primarily for military space systems that increase international tensions. Far from justifying the threats they pose to the environment and to scientific missions, many applications of orbiting nuclear power supplies are a threat in and of themselves.

A Ban on Nuclear Power in Orbit Would Be Readily Verifiable

Because space nuclear power supplies possess a variety of distinguishing characteristics, an international agreement to prohibit their use in orbit could be verified with high confidence.

In the first place, these systems necessarily operate at high temperatures. (This allows the size and mass of the radiator panels to be kept at a minimum.) They therefore give off a strong infrared signal which can be easily detected.

Operating reactors also emit strong gamma and neutron radiation signals which can likewise be easily detected. Indeed, the type of interference that has disrupted the scientific missions described above is uniquely produced by orbiting reactors and is a highly reliable, though unwelcome, sign of their presence.[11]

---

[11] Detailed studies of the verification of a ban on nuclear power in orbit have been conducted by the Federation of American Scientists/Committee of Soviet Scientists Working Group on Space Nuclear Power. See David W. Hafemeister, "Infrared Monitoring of Nuclear Power in Space," and Joel Primack, Philip Pinto and Oleg Prilutsky, "Detection of Space Reactors by Their Gamma and Positron Emissions," in Science and Global Security, vol. 1, no. 1 (1989).

Conclusion: Ban the Use of Nuclear Power in Earth Orbit

The use of space nuclear power has greatly enhanced the U.S. space program in planetary exploration missions that would have been impossible without its use.

But while acknowledging these important benefits, one must also clearly acknowledge the disadvantages and dangers of space nuclear power.

There is a significant historical failure rate involving nuclear powered missions, including several substantial releases of radioactive materials. The trend toward increasing power levels and operating lifetimes will mean an increase in this environmental hazard.

The use of nuclear power in orbit degrades the quality of the near-Earth environment and jeopardizes the successful operation of other satellites through gamma ray pollution and collisions with orbital debris.

The current and many of the proposed applications of nuclear power in orbit are provocative and destabilizing. In those cases where this is not so, non-nuclear power sources are an acceptable alternative.

We therefore advocate an internationally binding agreement to ban the use of nuclear power in Earth orbit.[12] This readily verifiable measure would eliminate the hazards of nuclear power in orbit, enhance international stability, and help to protect the space environment, while fully preserving the possibility of using nuclear power for deep space scientific and exploratory missions.

---

[12] A senior Soviet Foreign Ministry official told a visiting FAS delegation last year that if the U.S. were to propose a ban, and "if such a matter were to be mutual, it would be very seriously considered" by the U.S.S.R. See Testimony of Daniel Hirsch, Federation of American Scientists, in "Cosmos 1900 and the Future of Space Nuclear Power," hearings before the Committee on Energy and Natural Resources, U.S. Senate, September 13, 1988, pages 109, 261.

Responses to Written Question Submitted by Chrm. Gore to Dr. Rosen

Aeronautical R&D Goals

In 1985, the Office of Science and Technology Policy issued a report entitled "National Aeronautical R&D Goals: Technology for America's Future." That report was followed by another 1987 report entitled "National Aeronautical R&D Goals: Agenda for Achievement."

Question 1: How successful has NASA been in implementing its portion of the "Agenda for Achievement?"

Answer 1: NASA has been moderately successful in implementing its portion of the "Agenda for Achievement". Our work with industry to determine the most promising concepts for future high-speed civil transports has made good progress. The High-Speed Research initiative in FY 1990 will address the critical environmental issues of atmospheric impact, sonic boom, and community noise. Cooperative efforts with the FAA in the areas of aviation safety and National Airspace System productivity have been enhanced. New agreements on wind shear/adverse weather and tilt rotor certification have been negotiated with the FAA and we are actively cooperating in the areas of aging aircraft and human factors.

Question 2: Of the eight goals of this "Agenda," where has NASA met with the most success? the least success?

Answer 2: NASA has met with the most success in encouraging long-term government R&D. Emerging, high-payoff technologies such as high-temperature engine materials, advanced propulsion concepts, and advanced composite materials have received increased emphasis. The advanced computational capability of the Numerical Aerodynamic Simulator (NAS) has been recently enhanced with the addition a second high-speed processor. Last year more than 1150 researchers, working on 350 projects, accessed the NAS from 110 remote sites. A 5-year comprehensive wind tunnel revitalization program was also initiated in FY 1989 to assure the health and productivity of NASA's major facilities. Progress has been slower in efforts to strengthen American universities for basic research and science education. The Center for Turbulence Research that has been established with Stanford University is providing excellent results and the Advanced Aeronautical Systems Design Program continues to evolve innovative design concepts and strengthen university/NASA relations.

Question 3: What has been done to address the most crucial problem facing U.S. aeronautics--the fact that government and industry leaders underestimate the depth and determination of foreign aeronautical commitment and the magnitude of the required R&D effort?

Answer 3: The U.S. industry and government recognize the strength of the international competition in aeronautics and have taken steps to address the challenge. The industry has worked closely with NASA to identify the competitive factors and develop strategies and plans to address them. The NASA Aeronautical strategy is based on exploiting those high-payoff, emerging technology areas that are required for preeminence in aeronautics.

We have worked with industry and other government agencies to integrate our efforts and to ensure that the magnitude of the challenge is understood. A Civil Aeronautics Technology Development and Validation Plan was prepared in 1988 at the request of the Senate Committee on Commerce, Science, and Transportation. This plan has been coordinated with industry and defines the technologies required for leadership in civil aviation. With the addition of those technologies needed for superiority in military aircraft, this forms the foundation for a comprehensive agenda which NASA is addressing methodically within a restrained fiscal environment. The FY 1990 High-Speed Research initiative is a strong step towards securing lasting U.S. leadership in aeronautics.

Market Share

In a recent briefing, Dr. Ballhaus, you indicated that the U.S. market share for jet transport orders had steadily declined over the last 20 years from 91 percent in 1969, to 84 percent in 1979, to 68 percent in 1987.

Question 4: What has been the principal reason for this decline?

Answer 4: The principal reason for the loss of U.S. market share is the emergence of strong, credible foreign competition from Airbus Industries. Airbus has captured an average of about 25 percent of the market during the 1980's. The Airbus success is based on a strong technology development and application program, the development and use of highly productive and capable facilities, and backing with government support and commitment

Question 5: Isn't it true that the decline for commuter aircraft and rotorcraft has been even more dramatic?

Answer 5: Yes, in particular, foreign manufacturers have captured the entire U.S. and world market for commuter aircraft with passenger capacities greater than 19 seats.

Question 6: Does the U.S. now have in place a concerted effort and strategy to regain market share in each of these areas -- subsonic, commuter and rotorcraft?

Answer 6: Last year, in response to a congressional request, NASA prepared a Civil Aeronautics Technology Development and Validation Plan that, if implemented, could provide a sound technology base for improving the U.S. aviation competitive position in the future. This plan addresses the critical technology needs for three important civil aircraft markets--subsonic transport, civil tilt rotor and commuter, and high-speed civil transport. Each of these markets is important to the country's long-term aeronautics strategy. However, for the commuter aircraft market it must be recognized that there are also many other factors that influence the U.S. industry's ability to respond. These factors include the current general aviation manufacturer legal liability situation that places a considerable financial burden and limits the ability to pursue new aircraft programs for the same manufacturers that also produce U.S. commuter aircraft. Another major factor is the commuter market fragmentation that has resulted from the recent emergence of many foreign manufacturers competing for the same commuter aircraft market.

Wind Tunnel Revitalization

In November 1987, NASA submitted a "Major NASA Wind Tunnel Revitalization Program" and five--year plan to the Committee -- an initiative strongly endorsed by the Committee.

Question 7: What is the status of this program, and does the FY 1990 Construction of Facilities budget request of $64.2 million keep this program on the proposed schedule?

Answer 7: The program is being implemented as planned. Currently, the CoF activities for the FY 1989 and 1990 projects are generally on schedule and within budget. The FY 1990 CoF budget request of $64.2 million will keep the program on schedule?

Question 8: With full funding in FY 1990, will the runout for this initiative still be roughly $85 million through FY 1993?

Answer 8: The funding profile for this initiative is still as originally reported, with full funding for FY 1990 the runout is $148.5 million through FY 1993. the $85 million figure cited above covers the period FY 1993-1993.

Question 9: What new aeronautics test facilities would be required if the decision were made to proceed with the development of a high-speed commercial aircraft and/or an aerospace plane.

Answer 9: The only new aeronautics test facility required for high-speed transport development is the Supersonic Low Disturbance Tunnel currently included in the proposed NASA FY 1990 Construction of Facilities budget. Now new facilities are required for the development of the NASP X-30 research aircraft. The future development of operational hypersonic vehicles will require additional test facilities that are currently being defined by NASA and the DOD.

Question 10: Are the facilities requirements for new aircraft substantially reduced with the advent of numerical aerodynamic simulators, or will there always be a need for test facilities?

Answer 10: The facility testing requirements associated with the development of new aircraft have changed character somewhat with the advent of major advances in computational capability. In addition to their prior development testing role, the test facilities are also being used to provide detailed experimental data to validate new prediction methods. For the foreseeable future, it appears that there will continue to be a major requirement for test facilities for developmental testing and to complement the computational capabilities.

Computer Aided Activities

In the FY 1990 NASA budget submission, you indicated that remote users are tied into the NAS facility and that the system supports 1,000 users on 335 projects at over 100 sites.

Question 11: For the record, would you please provide the Subcommittee with a breakdown of these activities and primary projects they support?

Answer 11: The NAS capability supported projects in the following discipline aerodynamics, hypersonics, turbulence, chemistry, structural mechanics, material sciences, atmospheric sciences, mathematics, electrical engineering, astrophysics, computer sciences, and life sciences. A complete breakdown of the projects supported in the operational year just completed (March 1, 1989 - February 28, 1989) is attached. Also attached are the annual report and technical summary of the projects for the previous operational year (March 1, 1987 - February 28, 1988).

Question 12: How does the current availability of computer time at the facility compare with the demand?

Answer 12: During the past operational year (March 1, 1988 - February 28, 1989) the requested computer time was approximately twice the time available and the facility ran at full capacity 24 hours a day and seven days per week.

Question 13: Is access to the facility prioritized, and what is the order?

Answer 13: Access is granted through an allocation process which is prioritized according to general guidelines of technical quality, need for NAS capability, timeliness, and national importance. Within NASA, priorities are determined by program needs. Computer time for other than NASA programs is allocated based on peer review of the proposals which are judged according to the guidelines above. Nationally important programs such as the National Aero-Space Plane (NASP) and space shuttle redesign are given the highest priority.

Question 14: With the addition of the Cray YMP supercomputer, will there be a better relationship between supply and demand?

Answer 14: With the addition of the Cray Y-MP supercomputer, the amount of computer cycles in the NAS facility has been tripled and two-thirds of those cycles have twice the performance. However, we believe that the demand for NAS computer time will continue to exceed the time available. For example, with each passing year more complex problems are being addressed with high-performance computing techniques as computing capabilities increase. Challenges in aerospace technology such as integrated vehicle system simulation and turbulence physics continue to exceed the computation power available.

NASP Budget

In September 1988, pursuant to the MOU between NASA and DOD, a new NASP funding profile was agreed to.

Question 15: In addition to the $127 million in the budget request for Transatmospheric Research and Technology, are there any additional FY 1990 funds in the NASA base program budget for NASP-related activities as there have been in prior years?

Answer 15: The total NASA request of $127 is in the TAV line. There are no additional FY 1990 funds in the base.

Question 16: What ongoing or planned NASA programs will directly benefit from the national aerospace plane technology program? And, what was the principal reason NASA entered this joint technology with DOD?

Answer 16: NASA programs in future space transportation and aircraft systems can benefit from NASP derived technology. Technologies that would find most application are light-weight, high-temperature materials and structures, fully developed and calibrated CFD codes, and advanced design tools (especially for vehicles with highly integrated engine and airframe).

NASA entered into a joint technology program with the DOD to develop technology for future civil and military aerospace vehicles that use airbreathing propulsion. The technology could enable single-stage-to-orbit vehicles that operate like airplanes and take off and land horizontally. An additional fall-out of NASP would be the possible two-stage to orbit vehicles.

Question 17: What percentage of the available computer time at the Numerical Aerodynamic Simulator at the Ames Research Center is dedicated to the aerospace plane program? Will this rate of utilization continue during Phase 3 of the program?

Answer 17: Between 30 and 50 percent of its available time. The rate should be lower during Phase 3, when only one configuration is being developed.

Budget Reduction Option

There has been some discussion of NASA/DOD down selecting from the six NASA configurations now being assessed -- two engine concepts for each of the three airframe concepts to one or two concepts -- in FY 1989.

Question 18: If such a down selection were made, would that FY 1990 budget request be reduced?

Answer 18: The JPO reviewed the Engine Test Module of Pratt and Whitney and Rocketdyne in May of 1989. The decision was to continue both contractors for the near term. Therefore, the FY 90 budget cannot be reduced.

Question 19: In addition to the early down selection option, are any other measures being considered to reduce the FY 1990 budget request or to rephase the program?

Answer 19: The Space Council has considered various alternatives for the NASP program. These include delaying the completion of Phase II by one to two years. These delays would mean the decision to build the airplane would be delayed one to two years.

Question 20: What are the consequences/risks of stretching out Phase II of the program and putting off the experimental aircraft, X-30, development decision?

Answer 20: Program stretchout or delay in the X-30 decision would impact the momentum built around the country. There are 5,000 people in government, industry, and the universities working on the program, including some 200 companies in 40 states.

Industry Financial Support

The NASP program includes substantial corporate funding and an innovative materials consortium.

Question 21: In addition to the FY 1990 NASA request of $127 million and the DOD request of $300 million, what is industry expected to invest in FY 1990? How much has industry invested to date?

Answer 21: In FY 1990, the industry is expected to invest $200 million. To date, they have invested about $500 million.

Question 22: Does the current program plan assume the continuation of a cost sharing regime during the experimental aircraft development phase?

Answer 22: The current program plan does not assume contractor contribution in Phase 3.

Question 23: Would industry be willing to increase its contribution to Phase 2 if there were a commitment to Phase 3? Do you believe the current industry contribution is at the appropriate level?

Answer 23: I believe that industry contribution is appropriate and significant. Budget cuts that would lead to a delay in the program will cause them to decrease their contributions in the current Phase 2.

Question 24: What does the development of a NASP prototype mean to future government/industry collaborative efforts? If the Congress kills this project, what are the consequences?

Answer 24: Presumably these questions mean the X-30 research vehicle and not a prototype which is a development step toward an operational vehicle.

The NASP program is an outstanding example of effective and productive government/industry collaboration. To hold out the promise of the X-30 vehicle and encourage companies to invest their own funds, and then have Congress kill the program, would do serious damage to such collaborative efforts in the future.

Question 25: What served as the basis for the creation of the Industry Materials Consortium, and what benefits have been derived from this concept? How are the costs of the consortium allocated? Have the benefits of this program spun off to other programs? Will they?

Answer 25: The NASP program management and the prime contractors realized that suitable light-weight, high-temperature materials and structures were critical to the development of the X-30 and that an accelerated materials development activity was necessary to be ready for the X-30 decision. They formed the materials and structures consortium as a way to solve this problem.

The benefits to date have been an extensive sharing of data, both from NASP funding for the consortium and from their own IR&D funds in related areas. The program office worked with the contractors to decide which materials each would focus on. Then the program office allocated the funds to the companies.

The products of the materials and structures consortium will find broad application in many other areas, especially in future space transportation vehicles and aircraft. The weight of combustion engines of all types could be dramatically reduced by the application of this technology.

Question 26: Do you agree with the premise that a significant percentage of today's manufacturing techniques will not be applicable to future aerospace systems and that programs like NASP stimulate the development of these manufacturing technologies?

Answer 26: This is true, especially with the broader application for advanced composites in all aerospace systems. The NASP is already stimulating new manufacturing approaches for the fabrication of the X-30.

Facilities Requirements

The Air Force Scientific Advisory Board was scheduled to meet in February and to review the facilities requirements for NASP.

Question 27: Based on the assessment, what additional facilities requirements are there for the program? Would these be NASA or DOD facilities requirements?

Answer 27: NASA participated with the USAF Scientific Advisory Board (SAB) to review the needs for additional hypersonic facilities for the future DOD and NASA needs, not limited to NASP.

Facilities needed to complete Phase 2 of the NASP are available, however, some additional facilities for structural testing of X-30 airframe components and for flight testing the X-30 at NASA Dryden and Edwards AFB will be required in Phase 3. Also, some upgrades of existing facilities, such as selected ones at AEDC, will need to be done.

Question 28: What are the current facilities capabilities in the U.S., and what is the highest Mach test regime for engines and airframes?

Answer 28: The capabilities of U.S. facilities at the NASA Centers, at AEDC, at other government laboratories, and industry for testing components for the X-30 are adequate. For near full scale engine testing we are limited to about Mach 8, and this is the capability of the upgraded engine test facilities the NASP program has funded at Marquardt and Aerojet. Components of airframe and scramjet engines can be tested at Mach numbers up to 25 in the pulse type-facilities. Rocketdyne recently broke ground for a new pulse facility for the NASP program with $20 million of their own money.

Question 29: Do you agree with the proposition that in addition to these ground facilities we need a "Flying Wind Tunnel" to test a prototype at Mach 8?

Answer 29: We need the X-30 research vehicle to explore the entire airbreathing flight envelope from ground to orbit. As mentioned, the limit of near full scale engine testing is about Mach 8. We need the X-30 to explore the region from Mach 8 to approaching Mach 25. The X-30 can be viewed as a flying wind tunnel, and will be used to validate CFD analyses, and to demonstrate the NASP technologies no just to Mach 8 but to Mach 8 and beyond. Once again, it is not a prototype, but a flight research vehicle and technology demonstrator.

Question 30: Does this mean that initiation of the In-Space Experiments Program was higher priority than increased funding for the Pathfinder Program?

Answer 30: Initiation of the In-Space Technology Experiments Program is consistent with OAST's strategic plan to conduct a strong, balanced research and technology program, using ground and space-based research. In the past, funding constraints and the high cost of flight experiment have limited the OAST program to one that is primarily ground-based, not allowing sufficient opportunity to validate technology in the actual space environment. This initiative is a step forward to provide balance to our program by supporting both ground-and space-based research and is not in competition with the Pathfinder program or any other program within OAST. Validation of technologies in the actual space environment, when required, is the necessary extension of the OAST programs to reduce the risk of advanced technology concepts and to ensure that the new ideas and innovative technology concepts that are developed within the research facilities of the U.S. industries, universities and the government can be utilized more quickly by the designers of advanced spacecraft.

Question 31: Would I be correct then if I ranked the order of priority of these three technology initiatives as:

1. Civil Space Technology Initiative,
2. In-Space Experiments, and
3. Pathfinder

Answer 31: The goal of the OAST program is to provide advanced technologies to enable and enhance future civil space missions and to provide a solid base of capabilities and talent to serve all national space sectors. To accomplish this, OAST has developed a strategic plan that carefully balances many requirements: ground and flight experiments, basic and focused research, and near-Earth and solar system exploration. The focused research, and near-Earth and solar system exploration. The focused programs, Civil Space Technology Initiative, Pathfinder and the In-Space Technology Experiments, as well as the Research and Technology Base, are key and complementary elements in a strategy that is balanced and responsive to a range of important national priorities. These elements represent a critical investment necessary to maintain progress toward our future space goals.

Question 32: Of the 47.3 million requested for the Pathfinder Program in FY 1990, how much of this funding represents activities that were part of the base program in FY 1988?

Answer 32: Some of the programs in Pathfinder grew out of activities that were ongoing in the OAST Space R&T Program in FY 1988. In particular, approximately $18-19 million of the FY 1990 Pathfinder budget derives from activities that were being conducted in the ongoing program -- about $8-9 million under the Research and Technology Base in FY 1988 and $10 million for NASA's continuing contribution to the important SP-100 space nuclear power program under the Civil Space Technology Initiative. These R&T Base activities, however, were of a substantially different character from the focused technology efforts initiated under Pathfinder.

Question 33: Why is the amount of funding for studies in the Pathfinder Program increased in FY 1990? Wouldn't this money be better spent on technology activities?

Answer 33: Technology activities conducted under the Pathfinder Program are currently in a start-up mode. A balance has been set by the Agency between the start-up activities within the several technology programs of Pathfinder and the share of resources for the Office of Exploration for mission studies. There is a positive and continuing relationship defining mission requirements and technology needs as part of the planned efforts within Pathfinder and the ongoing mission studies conducted by the Office of Exploration.

Question 34: In light of the reduced funding in FY 1989 and the reduced request in FY 1990, has the decision date for the next major initiative been slipped from 1992 to the late 1990s?

Answer 34: At the present time, various alternate strategies are being considered for decisions on, and implementation of, future exploration missions. Pathfinder is not directed toward any single mission option, but provides a broad technology foundation for an array of future potential piloted and robotic solar system exploration missions. The research and technology results from Pathfinder will provide substantially improved design data, reduced risks and costs that will support future decisions on potential major initiatives.

The funding levels in FY 1989 and FY 1990, which are lower than our original plans, will result in program reductions in scope and substantial delays in program deliverables, including engineering and technology data to support informed national exploration mission initiative decisions. Current budget levels will not provide originally planned levels of technology data or readiness for the broad array of potential missions supported by Pathfinder until the late 1990s timeframe.

Question 35: Is that slippage consistent with the Bush Space Policy, and has the focus on major goals and initiatives now been isolated to a discussion of implementation of the space station program and the Mission to Planet Earth?

Answer 35: Overall funding reductions in Pathfinder, and the resultant delay in program deliverables, has resulted from current year funding constraints, not from a fundamental policy reassessment of the national goal of solar system exploration.

Implementation of the Space Station will be the key to future Agency efforts in all areas of civil space leadership. In conjunction with the Space Station program, an increased understanding of our Earth through space-based observations represents one essential ingredient of the U.S. future in space.

The goal of solar system exploration remains one of the overarching objectives of the U.S. civil space program. Pathfinder, which will develop and take to readiness the technologies needed for exploration, remains a key element of the Agency's near-term investment planning to ensure long-term civil space leadership.

Question 36: The FY 1990 Budget request includes a proposed new start for the In-Space Experiments Program. What is the proposed focus of this program, and what specific technologies would be addressed?

Answer 36: The In-Space Technology Experiments Program is a vital element of the OAST strategy to revitalize our technical capability and to establish a proper balance between ground-based and in-space research. This initiative will focus on developing flight experiments to test highly innovative technologies, identified through ground-based research that require research, testing, and validation in the space environment in order to understand basic phenomena, reduce risk to potential users and increase the rate of technology transfer to future space missions. In addition, an integral element of this initiative is to provide industry and university communities the opportunity and access to space for technology experiments.

Examples of specific technologies requiring in-space experimentation are: fluid behavior in microgravity environments (critical to the design of advanced thermal management, power, propulsion, and life support systems); the use of robotics in space construction, servicing and other in-space operations; and environmental effects on materials from long-term exposure to the space environment.

Question 37: The FY 1990 Budget request includes a proposed new start for the In-Space Experiments Program.

What is the proposed duration of this project and the spending profile?

Answer 37: The In-Space Technology Experiments Program is proposed as a continuing component of the OAST Space Research and Technology program with a spending profile of approximately $70 million over the next five years.

Question 38: If your office assessing a new possible global change research and technology initiative in FY 1991? What is the scope and status of this proposal?

Answer 38: OAST is planning a new initiative to develop technology in support off the OSSA Global Change Science program. The proposed Global Change Technology Initiative will address the technologies for LEO application related to Earth Observation System (Eos) needs, either as high payoff, higher risk backups for planned capabilities or for future upgrade or replacement platforms, as well ad the long led, high priority technologies that need to be started now to enable future LEO- and GEO-based observations of the Earth. The goal of the proposed initiative will be to develop the key technologies to enable and enhance the future long-term observation, documentation, and scientific understanding of the Earth as a system. This initiative will focus on technologies (1) to enable and enhance observations, 92) to handle and deliver the massive quantities of data, and (3) to ensure long spacecraft operating life.

This proposed initiative will build upon the experience and expertise within NASA to pursue the technologies needed to observe global change, as well as recent OAST study efforts to identify needed technological advances. Future Earth science missions require the development of advanced technology now to reduce the technical risk and to enable the mission objectives. The scope of the initiative is being defined as part of the planning process and will be made available when the work is complete.

Question 39: To what extent does the existing space research and technology program address critical elements of a global change research program such as data visualization/ classification, world modeling data systems, optical communications, data management, etc.?

Answer 39: The OAST technology program is a balanced program designed to address the technology needs of future NASA and national space missions and systems. Some of the needs of Earth observing missions are covered by the ongoing program. However, the Eos and other potential advanced Earth science missions represent a major effort and commitment to the challenge of understanding the potential for global climate change. Specific key needs for Earth science missions in the technologies for observations, information, and long operating life systems are not being addressed by the current program. It is essential that an advanced technology program be initiated to reduce the technical risk, allow for future growth and expansion of capabilities, and lay the groundwork for future expanded capabilities in both LEO and GEO.

As an example, current OAST activities in data visualization are focused on the remote control of robotic systems (telerobotics). Another example is Optical Communications, which under the Pathfinder program, will provide the technology for deep space communications in keeping with the exploration focus of the Pathfinder program. However, because of the importance of Optical Communications from LEO to earth, as a technology capable of handling and delivering the enormous quantities of data that will be generated by Eos and other advanced LEO and GEO Earth science platforms, a flight experiment is proposed under the OAST Global Change Technology Initiative to advanced this technology to the point where it can be used in future near-Earth application. Finally, the CSTI High Rate Data program, which is developing flight processors for data handling and processing and read/write optical discs for data storage, is directly applicable. Further technology developments are required in the ground-based access and retrieval to develop the capacity to sort, organize, classify, and retrieve information from large-scale data bases comprised of space-based observations, correlated ground truth measurements, and model-based data.

University Space Engineering Research Program

Nine University Space Engineering Research Centers were selected in FY 1988 to expand the Nation's space research and technology and to foster interdisciplinary research and industry/university collaboration.

Question 40: What is the status of this program? And when you do anticipate solicitation for a second round of proposals?

Answer 40: The University Space Engineering Research Program got off to a great start with the announcement of nine universities in April 1988. On January 24, 1989, all nine university center directors and OAST personnel met for the first time to discuss progress and status of the program. The universities and OAST agreed upon a three-step evaluation mechanism: (1) a NASA-wide Technical Representative Committee assigned to each university program; (2) an annual university national symposium; and (3) an annual meeting to be held at NASA Headquarters.

Our first priority is to fully fund the incumbent universities before starting additional centers. Expansion of the program is planned when additional funding is made available.

Question 41: Am I correct that when a second round is initiated, the guidelines will be revised to permit the participation of foreign faculty members who are at U.S. universities? Why is this change being instituted?

Answer 41: Yes, the guidelines will be revised for the second round to permit the funding of foreign faculty at U.S. universities. The intent of the program is to increase the number of U.S. graduates in space engineering. Faculty are not part of this goal, but are integral to conducting high quality research, regardless of nationality.

Question 42: Will funding still be limited only to U.S. students if there is a second round?

Answer 42: Yes. One of the major goals of the University Space Engineering Research Center Programs is to increase the number of U.S. students pursuing space engineering studies. The program will continue to focus funding on undergraduate and graduate students, research assistants, and post-doctural and sabbatical participants who are U.S. citizens. Recruitment and retention of U.S. students will be one of the annual evaluation measures of each grantee's success.

Question 43: Has the level of university space research and technology been engineered over the last few years?

Answer 43: Yes. As well as continuing two ongoing university programs that provide support for individual researchers and for engineering courses, OAST allocated $4 million to initiate the University Space Engineering Research Center (USERC) program in FY 1988. OAST then augmented the USERC program by an additional $10 million in FY 1989 to support the initial growth of the nine incumbent centers and to fully fund each center at $1-2 million per year.

Question 44: What is the current distribution of NASA space R&T dollars between industry and universities and NASA in-house activities? What is the trend in the distribution of these funds?

Answer 44: For FY 1989, universities comprise 17 percent of the total OAST Space R&D funding compared to 37 percent for industry and 33 percent for in-house activities. (The Jet Propulsion Laboratory receives the remaining 13 percent.) The funding distribution of OAST R&D demonstrates increased support for university activities; the FY 1988 level was 13 percent and the FY 1987 was 11 percent. The upward trend is attributed primarily to initiation of the University Space Engineering Research Program.

SP-100 -- Space Based Nuclear Power

NASA recently submitted a report to the Subcommittee on "NASA's Need for Advanced Nuclear Power sources." This report determined "that the development of a safe, high-capacity space nuclear reactor power capability is believed essential for the successful execution of many of the potential future space ventures being investigated."

Question 45: What NASA missions require space nuclear reactor power capability? and how many of these missions are earth-oriented operations or low earth orbit operations? Could these missions be implemented with an alternative power source?

Answer 45: Potential lunar and Mars bases and large scale interplanetary cargo transfer operations will require several hundreds of kilowatts to a few megawatts of electric power. These missions cannot be implemented with an alternative power source. Future NASA unmanned solar exploration missions could benefit from power sources of 30 to 120 kilowatts. Missions of this type to the inner planets could be accomplished, with some difficulty, using solar power. However, outer planet missions would require reactor power. Earth oriented operations such as resource processing in space, high power tracking and earth-observation systems could benefit from nuclear power. There are no missions of this type which have been defined to-date.

Question 46: What are the NASA power requirements for nuclear power in kilowatts? And, what is the focus of SP-100?

Answer 46: Several future NASA missions will require 100s of kilowatts of electrical power. SP-100 is developing the reactor technology capable of producing 2.5 MW thermal power which coupled with several alternative power conversion systems can deliver 10's to 100's of kilowatts of electrical power.

Question 47: If DOD were to drop out of the SP-100 program, would the power requirements change? What would change?

Answer 47: The power requirements would not change. Some unique DOD mission requirements such as survivability to hostile threats would be eliminated.

Question 48: What is NASA's position on the Brown bill, H.R. 966, that would ban the use of nuclear power sources in orbit around the Earth? What is DOD's position?

Answer 48: NASA disagrees with the proposed Bill. Future larger planetary and deep space mission spacecraft may benefit substantially from the use of reactors for electric propulsion and onboard power. These spacecraft are expected to be assembled, checked out, and deployed from Earth orbit to fully exploit the benefits to be gained from the use of electric propulsion. This will require the start-up of the reactor in earth orbit.

In addition, an earth orbit ban could prematurely foreclose opportunities for significant commercial benefits from large-scale, microgravity materials processing facilities operating in low earth orbit, as well as societal benefits from large geosynchronous orbit communications platforms, global observation and sensing platforms for which large amounts of power undoubtedly will be required. A compact nuclear power source may well be the most practical power system option for such applications.

Question 49: If this bill were amended to permit assembly and check out of space nuclear power sources in low earth orbit for deep space or lunar activities, would NASA's objections to this bill be addressed?

Answer 49: No. Deep space exploration spacecraft need to be deployed from LEO and operated in earth orbit to fully exploit the performance benefits that can be gained from use of electric propulsion. As previously stated, a ban would prematurely foreclose the benefits of nuclear power to a variety of potential earth orbit activities.

SP-100 Budget

Pursuant to a Memorandum of Agreement drafted in 1985, the funding obligations of NASA, DOE, and DOD for the ground engineering systems activity for SP-100 were established. That agreement was revised in 1986 to include SDIO in lieu of DOD.

Question 50: Has there been any further modification of those agreements in light of the recent budget reductions to SP-100? And what is the basis of the current interagency activities?

Answer 50: DARPA/DOD was one of three parties (NASA and DOE) that initiated the SP-100 program. DARPA's space activities were largely transferred to SDIO upon its formation and the MOA was changed accordingly in 1985. That MOA has not been changed, but we are currently evaluating the MOA with the intent of revising the funding chart to reflect increased NASA funding and reduced SDIO funding of the Ground Engineering System (GES) project.

Question 51: What is the proposed NASA contribution to SP-100 in FY 1990? And from what accounts are these funds drawn?

Answer 51: $10 million. SP-100 is part of the Pathfinder Program.

Question 52: How high a "technology" priority is SP-100? And if DOE and/or SDIO were to withdraw from this activity, would NASA pursue this program unilaterally?

Answer 52: As discussed in Question 45, space nuclear reactor power is essential for a number of potential NASA missions. If SDIO withdrew, the NASA need for nuclear power and the SP-100 program for potential future civilian space applications would still remain. DOE has the national charter for development of nuclear systems; NASA would likely pursue this program with DOE.

Question 53: Am I correct that during the FY 1990 budget deliberations, consideration was given to consolidating this program in DOE? What are the pros and cons of such a proposal?

Answer 53: Yes, preliminary consideration has been given to consolidating the program funding with the developing agency (DOE) provided that satisfaction of the user requirements could be ensured via users' programmatic direction and control. On the positive side, single agency advocacy and budgeting could help ensure multi-year funding stability. However, there is concern that the users (NASA and SDIO) could lose some influence on the program direction and control.

RTGs Versus Nuclear Power Generation

NASA currently uses Radioisotope Thermoelectric Generators (RTGs) for deep space planetary missions. As a matter of fact, two RTGs are scheduled for the Galileo and Ulysses missions.

Question 54: Why are RTGs inadequate for future missions?

Answer 54: As NASA moves forward with new, more sophisticated missions there will be a need to provide the additional power to conduct these missions. RTGs can provide power up to a kilowatt or so before they become too heavy relative to other nuclear options. Above about 10 kilowatts, reactors are the only nuclear option that is light enough for these missions. Thus, there will be a continuing need for RTGs on small science missions and a need for reactors on higher-powered missions.

Question 55: Has NASA or any other agency done a risk assessment comparing RTGs to nuclear generators? Does the RTG present greater risks than the nuclear generator because it involves the launch of "hot" plutonium, compared to uranium?

Answer 55: NASA is aware that the Department of Energy sponsored a study about five years ago comparing RTGs to reactors; however, that study, as we understand it, involved launch configurations and safety goals that are no longer being used. With regard to risk overall, we believe that both RTGs and reactors can be used safely.

Question 56: Does NASA have a formal advisory board to assess the risks and potential of nuclear power generators similar to the advisory board for RTGs? Should it?

Answer 56: NASA, through the SP-100 project, has safety boards which review the safety design of SP-100. Since SP-100 is not yet on a flight mission, there has been no need to establish the flight-related safety reviews that are currently being carried out on the RTGs to be flown on Galileo and Ulysses. When reactors are used for a mission, flight-related safety reviews of the type currently conducted for RTGs will be performed.

Recent Press Accounts

Recently, there were several press accounts about released Independent Review Board documents that highlighted serious problems and concerns with the SP-100 Reference Flight System. To quote from one section of that report, "the total or aggregated technical risk associated with the reference flight system design appears high and may be perceived by potential users to be incompatible with the stated objectives of validating the system by 1994." This review painted a very bleak picture.

Question 57: Would you please comment on these reports? and NASA's perception of the current status of this program?

Answer 57: The GES project is directed at developing and validating a space nuclear power system technology base; it is not a flight system development project. The reference flight system is a generic paper design established solely to guide the technology program. As a technology development program, the performance goals are, as would be expected, very challenging. The Independent Review Board was a group of technical specialist commissioned by the SP-100 project manager to assess the generic system design against program goals. The comments of the Board reflected the difficulty of the technology goals and an assessment of the progress.

Question 58: Have you met with the members or chairman of the Review Board to discuss their concerns?

Answer 58: No. The program personnel in my office are very familiar with the details of the report. The NASA Jet Propulsion Laboratory Project Manager has responded in detail to each of the comments provided by the board. A copy of the Boards's report and the Project Manager's response has been provided to the Committee.

Soviet Activities

At a Space Nuclear Power Conference held in January, Soviet scientist, participating for the first time, disclosed that they have put an advanced nuclear reactor in Earth orbit. They also indicated a willingness to sell this reactor to the West.

Question 59: Would your please comment on these revelations? And what is your assessment of the Soviet nuclear power generation technology?

Answer 59: From the presentations made by the Soviets, this new reactor appears to be based on technology they have been working on for over 20 years. The reactor produces about 10 kilowatts of electricity. The two new reactors flown operated for only six months in one case and about one year in the other case. From what we know of this technology, it appears that the designs are relatively low power, short-life systems. Our assessment is that this technology is not useful for future NASA reactor-powered missions where we will need hundreds of kilowatts for up to ten years.

Question 60: Are there any formal or informal discussions between the U.S. and Soviet Union concerning the use of space nuclear power?

Answer 60: As part of the January Space Nuclear Power Systems Symposium, both U.S. and Soviet papers were presented on a range of topics related to space nuclear power. Informal discussions related to the papers were held with the Soviets in an open forum among all of the participants at the Conference.

Question 61: In light of the Canadian experience with a reentered Soviet nuclear reactor, what is the view of the world community towards nuclear reactors in Earth orbit?

Answer 61: There have been discussions on the use of nuclear power in space at the United Nations since the 1978 reentry of the Soviet reactor-powered Satellite Cosmos 954 over Canada. The U.N. set up a special technical working group of experts, who concluded that nuclear power sources can be used safely in outer space provided that all necessary safety requirements are met. While individual delegations have expressed various opinions on the use of nuclear power in space, the consensus language adopted by all member delegations in 1981 allows for the use of nuclear reactors in Earth orbit.

Space Nuclear Power

The General Accounting Office (Report No. GAO/RCED-88-23; pp. 15-16) has estimated that the total costs of flight-testing an SP-100 reactor could be "more than $1 billion."

Question 62: Has NASA generated a different estimate? If so, please provide it to the Committee.

Answer 62: NASA has not defined a flight test program for the SP-100 reactor or developed cost estimates for such an endeavor. The cost estimate for the ongoing GES reactor technology development program is approximately $800 million. For a flight test, it is likely that a redesign of the GES article, based on knowledge gained in this ground testing phase, as well as upon those changes//additions essential to meeting space flight requirements would be required. Considering the cost of flight qualification efforts and launch system costs, we do not believe that the GAO cost estimate for this endeavor is unreasonable.

Question 63: A "nuclear safe orbit" has been defined as an orbit that has a minimum duration prior to possible reentry of 300 years or more.

Wouldn't the hypothetical use of nuclear power for a NASA space station or materials processing facility involve reactor operation at an orbit with a lifetime of less than 300 years, i.e., below a nuclear safe orbit?

Answer 63: Yes, but prior to proposing any low-Earth-orbit operations, NASA would have defined and developed the on-orbit systems and operational procedures that could provide operational safety assurance during the mission, as well as in accounting for the safe disposal of the reactor power system at the end of its life.

Question 64: News reports indicate that gamma radiation from Soviet nuclear reactors in orbit seriously disrupts the operation of certain other satellites.

Please describe the effects of orbiting reactors on the Solar Maximum Mission, the Japanese Ginga satellite, and the upcoming Gamma Ray Observatory mission. Would the disruptive effects of a 100 kilowatt SP-100 reactor be greater or less than those produced by a typical Soviet reactor in orbit?

Answer 64: According to published reports, the radiation effects appear to affect primarily the gamma-ray detectors on these satellites. The radiation effects are reportedly of two kinds: (1) direct detection of the gamma rays when the reactor is within the field of view and (2) detection of the gamma rays resulting from the annihilation of positions emitted by the reactor and trapped in the Earth's magnetic field. To some extent, in the case of the Solar Maximum Mission and the Gamma Ray Observatory, these effects can be overcome through predictive, operational, and analytical techniques. The Ginga satellite apparently lacks the reprogramming capability to deal with these events.

Comparing a derivative SP-100 flight system with a Soviet nuclear reactor is difficult given the uncertainties in Soviet operations. Moreover, the effects are related to orbital position relative to the sensing satellite and thermal power level. While one could argue that the presumed higher power level of a derivative SP-100 system would produce more direct gamma rays and positions, the U.S. policy of openness would lead to appropriate definition of the environment to allow scientists to take the necessary countermeasures.

Question 65: It has been reported that Soviet space reactors are disposed of in some of the orbits that are most densely populated with space debris. It has also been reported that the SNAPSHOT satellite, bearing the only space reactor launched by the U.S., has begun to break up.

Please comment on the potential for, and consequences of, interactions between nuclear reactors in orbit and the orbital debris environment.

Answer 65: Several years ago, the Air Force examined the possible explanations of the debris associated with the SNAP-10A reactor experiment known as SNAPSHOT. The Air Force concluded that "The failure of the on board ion engine is considered to be the likely cause of the debris, with the slow deterioration of the rocket body structure contributing to the separation of additional debris". The Air Force also concluded "...that there has been no damage to the reactor portion of the spacecraft". In this regard, it is interesting to note that a paper presented by the delegation from the Federal Republic of Germany (FRG) to a United Nations working group stated that storage or operation at altitudes higher than 1,200 kilometers would guarantee sufficient orbital lifetimes even for small fragments. SNAP-10A was placed in a 1,300-kilometer-high orbit.

The same German paper estimated an average of about 3 collisions during 300 years for every 100 nuclear reactors stored at an orbit 800-kilometers high (where at least three of the Soviet reactors are -- the others are higher). Given an impact, it is estimated that the target would be fragmented and the fragments would eventually reenter, perhaps within 50 years for an 800-kilometer orbit. Even 50 years would be helpful since the Canadian health physics studies on Cosmos 954 showed that there would be only a negligible risk from debris after about two years.

Question 66.(a): In 1988 the SP-100 program convened an Independent Review Board of government experts to assess the SP-100 reactor design. Its conclusions were severely critical of the SP-100. Please respond to the following assertions by the Review Board:

The SP-100 has a generic design which is "off-optimum for all users/mission applications." (page 5 of the Review Board's 6/28/88 report)

Answer 66.(a): The GES Project is focused on establishing an advanced space reactor power systems technology base (cutting edge technology) that could be capable of producing tens to hundreds of kilowatts of electrical power for extended time periods, to satisfy a range of future potential DOD and NASA missions. The technical difficulties are known to be significant but felt to be achievable and justifiable considering the added cost of multiple nuclear reactor technology efforts. The Review Group expressed an opinion that the SP-100 technology was trying to cover too broad a range of user requirements. Upon review, the project office feels that the development of a broadly applicable technology is achievable; however, the concerns of the board are recognized as valid and user requirements will be an area of continuing assessment.

Question 66.(b): "A critical weakness in the SP-100 program is power plant design beyond the range of available data. This deficiency occurs in so many aspects of the design that the entire program has extremely high risk."

Answer 66.(b): Since the SP-100 program is a technology development effort, as opposed to a flight system design and development effort, challenging performance and safety goals have been specified. The Independent Review Board critique was one part of an overall process to assess the generic system design and its validity to serve as the baseline for the space nuclear power technology validation effort. The reference system design review identified areas in which special technical difficulties exist and where corrective actions or design changes may be necessary. The project office has reviewed each of the recommendations of the Review Board and will make changes as required.